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No. 49

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CONTENTS (Continued)

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

INFORMATION ON CENTRAL STATISTICAL ADMINISTRATION

Moscow VESTNIK STATISTIKI in Russian No 7, 1978 pp 59-67

[Article by Candidate of Economic Sciences G. Ovcharenko, deputy chief of the USSR TsSU: "The Mechanization and Automation of Accounting and Statistical Work"]

[Excerpt] The 25th Congress emphasized the urgency of improving the accounting and reporting system and statistical information in accord with the growing needs of management and planning, and pointed to the necessity of further developing and raising the efficiency of the automated control systems and the computer centers, in consistently linking them into a single statewide system for data collection and processing for accounting, planning and management. The necessity was also recognized of setting up collective-use computer centers (VTsKP).

A qualitatively new stage of development has occurred for the computer system of the USSR TsSU [Central Statistical Administration]. It has begun to be intensely equipped with modern electronic and other computer equipment. The machine accounting stations and the mechanized accounting plants which have been equipped with electronic computers have begun to be converted into computer centers. On the rayon level a network of information computer centers (IVTs) and stations (IVS) has been set up.

Work has been started on the designing and development of the ASGS [Automated System of State Statistics].

The development of the computer system of the USSR TsSU can be illustrated by the following data.

Computer System of the USSR TsSU

(units at year's start)

	1958	1968	1978
Mechanized accounting plants	7	3	--
Computer (information computer) centers	--	14	466
Information computer stations	--	--	1956
Machine accounting stations	126	967	530

The computer system of the USSR TsSU is a network of various types of computer installations deployed over the entire territory of the country. It includes 171 computer centers on the Union, republic, and oblast (kray, ASSR) levels, and these prepare for the leading bodies, the economic leadership and for planning generalized statistical information on the socioeconomic life of the nation and its individual regions on the basis of both current reporting as well as broad and profound statistical research such as censuses, surveys, special analytical studies, and so forth.

The rayon level of the computer system of the USSR TsSU is of great significance. This unit has been set up on the basis of uniting the rayon (city) inspectorates of state statistics and the machine accounting stations and equipping them with various types of computer facilities. It includes 295 rayon (city) information computer centers of state statistics, 1,956 rayon (city) information computer stations for state statistics and 525 machine accounting stations. The rayon information computer centers are equipped with electronic facilities, basically with the M-5000 punch computer set. The information computer stations are characterized by the use of punch computer machines (sets).

Along with working out the reporting of the enterprises and organizations and preparing general statistical information, the computer system of the USSR TsSU carries out a broad range of work related to the mechanizing of accounting and the processing of accounting and statistical data for the enterprises and organizations of all the national economic sectors. By the beginning of the current year, such work was performed for 87,200 enterprises and organizations, including for 32,900 kolkhozes and sovkhozes and other agricultural enterprises, 10,200 centralized bookkeeping offices of budget-supported and self-financing enterprises and organizations. With the help of the computer organizations of the system of the USSR TsSU, full mechanization or accountancy was introduced at 2,400 enterprises and organizations, including 1,400 kolkhozes and sovkhozes. During the years of the Ninth Five-Year Plan, the volume of work of the computer system increased by 2.5-fold.

The computer system of the USSR TsSU employs 175,000 statisticians, economists, programmers, equipment operators and specialists from other professions. Their labor enthusiasm is manifested in the broadly developed socialist competition. More than 83,000 persons are participating in the movement for a communist attitude toward labor, and this includes 57,400 operators. By the start of the current year, more than 30,000 workers had been awarded the honorary title "Shockworker of Communist Labor," and 29,000 workers had completed ahead of time the fulfillment of the plan quotas for two and more years of the Tenth Five-Year Plan. A large detachment of statisticians and equipment operators has governmental decorations.

Let us give a few examples characterizing the development of the computer organizations of the USSR TsSU. The computer center [CC] of the Statistical Administration for the city of Leningrad and Leningrad Oblast has grown from a small subunit for the mechanized processing of statistical reporting set up

in 1927 under the Statistics Department of the Leningrad Oblast Executive Committee into one of the large oblast CC and a major regional CC for electronic data processing in the Northwestern Economic Region. It has 5 electronic computers, 57 sets of computer punching machines and 555 various computating machines. Along with elaborating all the statistical reporting of the enterprises and organizations in the city and oblast, it performs computer work for almost 200 enterprises and organizations. The CC employs over 1,000 persons and this close-knit collective has been the initiator of numerous patriotic undertakings in the socialist competition of the organizations of the USSR TsSU. Almost 750 persons are participating in the movement for a communist attitude toward labor, and around 150 operators have been awarded the title "Shockworker of Communist Labor." The CC collective has repeatedly been the winner in the all-Russian socialist competition.

One of the nation's largest computer organizations is the Central Computer Center of the USSR TsSU. In 1932, this was the first mechanized accounting plant within the system of the USSR TsSU; it was equipped with 6 sets of punching computers. At present the TsVTs [Central Computer Center] employs arouns 2,500 specialists, it has 6 computers, 124 sets of punching computers, 945 computational machines, 458 adding machines and 349 bookkeeping and billing machines. The annual volume of work done by the center exceeds 8 million rubles. Here basically they work out the materials of the diverse censuses and the one-shot statistical surveys. In recent years alone the TsVTs has successfully handled the working out of the materials of the 1970 All-Union Population Census, the reevaluation of the fixed capital of the enterprises and organizations of the nation and the fuel and energy balance; it has converted to the electronic processing of materials for the annual censuses of uninstalled equipment (with a significant reduction in the times and now a reduction in the cost of the work), and data from the surveys of the incomes of families of workers, white collar personnel and kolkhoz members and a number of other materials for the various areas of statistics. The 18 affiliates of the TsVTs process the economic information from the centralized bookkeeping offices of the budget-supported organizations of Moscow, and its 20 affiliates are large machine-accounting installations performing a large number of computational jobs for a multiplicity of enterprises and organizations in the city.

The TsVTs has repeatedly been the winner in the all-Union socialist competition among the computer centers of the system of the USSR TsSU. For achieving high indicators in the socialist competition in commemoration of the 100th birthday of V. I. Lenin, the collective of the GVTs of the USSR TsSU was awarded the Lenin Jubilee Honorary Diploma of the CPSU Central Committee, the Presidium of the USSR Supreme Soviet, the USSR Council of Ministers and the AUCCTU.

At present, the TsVTs of the USSR TsSU is carrying out extensive methodological, design and organizational work related to the preparations for processing the materials of the 1979 All-Union Population Census. There are plans to use completely new techniques for data processing and these

envisage the feeding of the initial information into the computer directly from the primary census document.

The Main Computer Center [GVTs] of the USSR TsSU is the final element in processing the statistical information from the state statistics bodies. It provides organizational and methodological leadership over the computer centers on the republic and oblast levels, it organizes the process of elaborating and introducing the systems plans for electronic data processing, and exercises control over the preparation of the statistical information and the quality of the computational work.

In working out the final data received from the computer centers of the TsSU system, the reporting of certain ministries and departments and a large group of industrial enterprises from the all-Union ministries, the GVTs prepares and issues statistical information on the fulfillment of the plans for national economic and social development. Each year the GVTs issues more than 6,000 summary reports. This center employs 11 electronic computers and much other equipment. With the aid of a display for solving certain problems the economists have direct access to the computer, and this makes it possible to obtain up to date reference information. The installed equipment makes it possible to transmit data under computer-to-computer conditions.

For high indicators in the all-Union socialist competition and for the successful fulfillment of the plans and accepted socialist pledges, the collective of the GVTs of the USSR TsSU twice in the Tenth Five-Year Plan (for 1976 and 1977) received the rotating Red Banner of the CPSU Central Committee, the USSR Council of Ministers, the AUCCTU and the Komsomol Central Committee.

The computer system of the state statistical bodies is being developed and improved on the basis of the continuous supplying of it with diverse computer equipment reflecting scientific and technical progress in the area of accounting and statistics.

Profound qualitative changes are occurring in the technical base of the computer system. In the place of electromechanical keyboard and punching computers, electronically-based machines of this class are being used. The second generation computers are being replaced by modern third generation machines (the YeS computers). Computer installations of the M-5000 punch computer type are being received in large numbers and these are designed to replace the electromechanical punchers.

Equipment for transmitting data over long distance telephone and telegraph communications channels are gaining wide spread, as well as highly productive machines for the operational reproduction of materials ("small-scale printing"), and other equipment.

A most important feature in the functioning of the computer system is the uniform work procedures at all the computer centers and machine accounting stations. This has been realized in the standard plans for the processing of large masses of data. It is based upon the use of uniform program, data and technical support.

During the current five-year plan, the number of computers in the computer system of the USSR TsSU will increase by approximately one-third. The system will receive third generation computers (the YeS computers) which have a high speed and a large capacity operational storage, and a developed system of external devices which will operate also under time sharing conditions. There will be extensive development to the system of data teleprocessing and the exchange of data over communications channels between the computer centers under automated conditions.

The experience of the computer system of the USSR TsSU indicates that the concentrating of data processing at large CC creates the necessary conditions for the efficient operation of modern computer equipment, it provides comprehensive elaboration of the accounting and statistical material with a reduction in the cost of the work, and makes it possible to minimize duplication in the collection, preparation, storage and processing of economic information, as well as to make rational use of the labor and capital expenditures in designing and introducing electronic data processing systems. The quality of designing is also raised.

The level of development of the computer system of the USSR TsSU and the experience acquired in the area of mechanizing the accounting and statistical work have provided an opportunity to begin creating the ASGS of the USSR TsSU.

The ASGS is an intersectorial multilevel system for the collection and prossessing of accounting and statistical information, and is to be set up for further improving the work of the state statistical bodies and its computer system on the basis of automating the processing of large masses of data and more fully satisfying the growing needs for statistical information to plan and manage the national economy. The ASGS is one of the basic functional elements in the statewide automated system being developed in the nation for the collection and processing of information for accounting, planning and management of the national economy.

The work of setting up the ASGS is being carried out in individual stages and sequences. At the end of the Ninth Five-Year Plan (1975), the first stage of the ASGS was put into operation. This made it possible to provide systems processing of around one-half of the volume of the statistical information prepared by the computer system of the USSR TsSU. The computer centers of the Union, republic and oblast (kray, ASSR) levels are now working under uniform informational, program-technological and technical conditions with the transmitting of the data processing results from the inferior to the superior level of the ASGS over communications channels or on technical carriers (magnetic tape).

As a result of putting the first stage of the ASGS into operation, there has been a significant increase in the volume of output information in the form of grouped and combination tables. This has made it possible to substantially increase the analyticalness of the general statistical indicators. And there has been a reduction in the time extended on processing the data, primarily the statistical reporting required for economic management and planning. The quality of information has risen due to automating the control in all processing stages.

More than 1,600 specific machine programs are being used for the functioning of the 46 system and 106 local (regional) electronic data processing complexes (KEOI). These have been compiled for each complex as standard ones for all the CC of a certain territorial (republic or oblast) level.

The functioning of the first stage of the ASGS has made it possible to process an enormous mass of accounting and statistical information the volume of which has risen by 41 percent during the years of the Ninth Five-Year Plan. The labor intensiveness of processing a unit of statistical information has declined by almost 60 percent. If the statistical information as before were processed on the punch and keyboard computers and not on electronic computers, this would have required at least 20,000 additional persons and in addition, annually around 2 million rubles of finances.

At present the work on creating the ASGS is being carried out in a direction of the further improvement and development of its first stage and the setting up of the second stage the fundamental feature of which is the creating of automated data banks (ABD).

The ABD of the ASGS is set up as an automated territorially distributed system which brings together the informational, program and technical means for data processing and provides the accumulation, storage, actualization, retrieval and printing out of the necessary statistical information. This work is based upon uniform methodological principles for the organization of the ABD, its informational fund and on the uniform program and technical support [software and hardware]. Here there is provision for the single inputting of data into the system and their multiple differentiated use.

The ABD of the ASGS will serve as an essential prerequisite for deepening data analysis on the basis of mathematical economics methods, analytical groupings and other statistical research procedures. The storage of both current data as well as data of dynamic series will make it possible to provide continuity in the information depiction of observed phenomena and processes. Naturally all of this will more fully meet the needs of the management and planning bodies for the required statistical information.

The creation of the ABD entails a further standardizing of the accounting forms and the report indicators, and consequently, a systematizing of the data flow.

In the area of developing mechanization and automation in accounting and statistical work, the USSR TsSU is collaborating fruitfully with the fraternal socialist countries which are introducing automated data processing systems into the practical work of their statistical bodies. The permanent working group on the automation of statistical information processing (PRG) which functions under the Permanent CEMA Commission for Statistics will make a valuable contribution to this.

The development of the computer system of the USSR TsSU will be carried out in the direction of renewing and strengthening its material and technical base, improving long distance exchange of data, creating an automated system of control for the computer network of the TsSU and the dispatching service which ensures the planned and rational load on the computer units and an improvement in the organizational forms for the use of computer equipment. All of this will make it possible to process the ever increasing volume of statistical information in the bodies of the USSR TsSU and will contribute to a further strengthening of the functions of its computer system in the area of the mechanized elaboration of accounting and computational work from the enterprises and organizations.

Particular attention is to be given to the introduction of the comprehensive processing of accounting and statistical data from the enterprises, construction sites, kolkhozes, sovkhozes and other organizations located within the zone of the CC. At present, in accord with the decisions of the 25th CPSU Congress, experimental collective-use computer centers (VTsKP) are to be set up, including four VTsKP of the system of the USSR TsSU which are to be organized on the basis of the republic computer centers in Tallin and Minsk and the oblast CC of the TsSU system in Tula and Tomsk. This work should become the basis for the further development and generalization of the experience existing within the system of the USSR TsSU for processing accounting, statistical and other economic information under collective-use conditions for the computer equipment, and above all for the computers themselves.

The improvement of the computer system of the USSR TsSU and the supplying of it with modern electronic computers and other computer equipment and data processing devices will serve the cause of creating a statewide network of computer centers.

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ENGINEERING AND EQUIPMENT

LASER LIGHT SOURCE ILLUMINATING DEVICE DESIGN FEATURES DISCUSSED

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY, PRIBOROSTROYENIYE in Russian Vol 21 No 6, 1978 pp 94-101 manuscript received 31 May 77

[Article by V.V. Khvalovskiy, S.N. Natarovskiy and V.I. Nalivayko, Leningrad Institute of Precision Mechanics and Optics: "An Illuminating Device with a Laser as the Light Source"]

[Text] Optical systems of illuminating devices with a laser as the light source are discussed. A technique is given for calculating the size of the area illuminated and the distribution of illuminance in the subject plane.

At the present time extensive use is being made in illuminating devices of lasers (OKG's) as the light source. A distinctive feature of a laser, distinguishing it from incoherent light sources, is the narrow directional effect of its radiation within the range of the light beam's angle of divergence, as well as the practical absence of a heat effect on the subject illuminated when operating in the visible wavelength range. The first feature makes it possible to avoid losses of light in the illuminating device because of the limitedness of the condenser's aperture, and the second eliminates the necessity of employing heatproof equipment. In addition, the optical system of an instrument constructing an image of the subject illuminated takes on new properties--image contrast is enhanced [1]. In comparison with illuminating devices for incoherent illumination, illuminating devices for coherent illumination have been studied relatively little. This is explained in part by the disadvantages of this type of illumination: by the occurrence of a grainy image structure and by the lower resolution of the optical system constructing an image of a subject illuminated in this way. But some of these disadvantages can be eliminated, and others considerably lessened. Obviously it will not be possible to eliminate image graininess totally, since this phenomenon is caused by interference effects in the "coarse" structure of the subject. But it can be reduced by altering the nature of this interference. Here we do not have in mind the case of illuminating the subject with a laser light beam passing through a matte glass diffusion plate, which will also result in smoothing out the graininess, but, however, at the expense of lowering the degree of coherence of the illumination [1]. It is possible to increase resolution by using indirect lighting, but here the so-called azimuthal effect can appear [2], for the elimination of which it is necessary to light from several directions.

Research carried out at LITMO [Leningrad Institute of Precision Mechanics and Optics] in conjunction with the USSR Academy of Sciences IZMIR [Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation] has demonstrated that, to eliminate these disadvantages of coherent illumination while retaining all its advantages, it is feasible to employ in the illuminating device a laser and lens screen combination. Here the lens screen, functioning as a phase diffraction grating, transforms the laser light beam into an infinite set of parallel-ray light beams. These beams are diffused in space at all possible angles to the optical axis of the illuminating device within the limits of the lens element's aperture angle. Here the phenomenon of diffraction at the edges of the screen's lens elements is disregarded, which is totally permissible for lens screens with the screen's lens elements measuring 0.2 to 0.4 mm and more. This laser and lens screen combination can be employed as an illuminating device for coherent illumination of both near and considerably far (infinitely far) subjects. Since the light effect of a laser and lens screen is equivalent to the light effect of an infinitely far extended coherent light source, an infinitely far subject will be illuminated coherently and omnidirectionally within the limits of the illuminating device's aperture. With this type of illumination light strikes each point of the subject from each point of the illuminating body of the light source or from each point of the illuminating device's exit pupil. If subjects are located at not too great a finite distance, it is a good idea to supplement this combination with a condenser (cf. fig 1), in whose rear focal plane the illuminated subject is placed, and sometimes with a collector, too (cf. fig 2). These illuminating devices can produce illumination by any method (Koehler, critical, etc.), as well as by both the dark and bright field method. A characteristic aspect of designing illuminating devices of this sort is the need to take into account the interference of illuminating light beams on the surface of the subject. Let us discuss a technique for designing illuminating devices constructed according to the arrangements shown in figs 1 and 2.

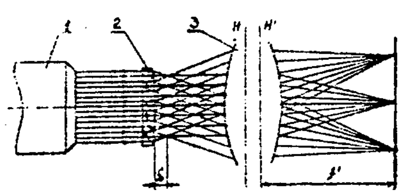

Figure 1.

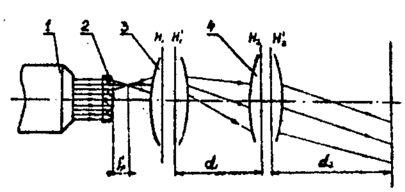

Figure 2.

In the first arrangement (cf. fig 1) the illuminating device contains a laser, 1, a lens screen, 2, and a condenser, 3, in whose rear focal plane the subject is placed. Let f'_r be the focal length of the screen's lens element, and f'_1 that of the condenser, and D the dimension of the entrance pupil of the screen's lens element. We assume that the condenser is a system unlimited in terms of diffraction. Then, in the rear focal plane of the condenser, an area of the subject will be illuminated measuring $2y'$, which can be determined from the following equation:

$$2y' = \frac{f_1'}{f_p'} \cdot D = 2f_1' \operatorname{tg} u',$$

where u' is the rear aperture angle of the screen's lens element.

It is obvious from this equation that it is possible to alter the value of $2y'$ by altering the values of f_1', f_r' and D. The distribution function of the amplitude field, $U(x,y)$, in the illuminated area is determined from the equation:

$$U(x, y) \simeq F\{T(x, y)\},$$

where F is the sign for the Fourier transform operation and $T(x,y)$ is the transmission function of the lens screen.

In turn,

$$F\{T(x, y)\} \simeq F\{T_p(x, y)\} F\{L(x, y)\},$$

where $T_r(x,y)$ is the transmission function of the screen's lens element and $L(x,y)$ is the packing function of the lens screen.

Ordinarily employed are orthogonal and triangular (hexagonal) packing of the screen's lens elements. In the first case:

$$L(x, y) = \sum_{n=-N}^{N} \sum_{m=-M}^{M} \delta(x - nX, \; y - mY),$$

where $\delta(x,y)$ is Dirac's delta function, X and Y are intervals of the lens screen along the X and Y axis, M and N are positive whole numbers, $|n| = 0,1,2,\ldots,N$ and $|m| = 0,1,2,\ldots,M$ and in the second case

$$L(x, y) = \sum_{n=-N}^{N} \sum_{m=-M}^{M} \{\delta(x - 2nX, \; y - 2mY) + \delta[x - (2n + 1) X, \; y - (2m + 1) Y]\},$$

where

$$X = \sqrt{3} \cdot Y.$$

Assuming that the screen's lens elements have negligibly slight aberrations, for function $T_r(x,y)$ we get [1]:

$$T_p(x, y) \simeq D_p(x, y) \exp[-j\alpha(x^2 + y^2)],$$

where $D_r(x,y)$ is the pupil function of the screen's lens element, $\alpha = k/2f'_r$, where $k = 2\pi/\lambda$, is the wave number, and λ is the wavelength of the laser's radiation.

The distribution of intensity in the plane of the illuminated area, $I(x,y)$, is proportional to the square of function $U(x,y)$. Omitting detailed mathematical transforms, we give in the table expressions for $U(x,y)$ with various forms of function $L(x,y)$ for a round and rectangular shape of the screen's lens element pupil. It is obvious from this table that the distribution of intensity (illuminance) in the illuminated area is determined by multiple-wave interference among illuminating light beams. In order for the resolution, ν, of the optical system constructing an image of a subject illuminated in this way not to be lower than in the case of incoherent illumination, it is necessary to fulfill the following condition: Two maximally resolvable points of the subject must be "secondary" light sources radiating out of phase. For this it is sufficient that the closeness of the interference maxima be not below the required resolution of the system, i.e.,

$$\nu_x = \frac{1}{\Delta x} = \frac{X}{\lambda f'_1},$$

where Δx is the distance between adjacent major maxima. Similarly, along the Y axis, $\nu_y = Y/\lambda f'_1$.

In the second sketch of an illuminating device (cf. fig 2), to simplify the drawing the path of rays through only one lens element of the screen is shown. The device consists of a laser light source, 1, a lens screen, 2, a collector, 3, and a condenser, 4. The illuminated subject is placed at a certain distance, d_2, from the condenser. Each such lens element leaves a light "trace" in the subject plane. The centers of these "traces" lie at the nodes of a mesh similar to the packing reticule of the lens screen, 2, and, if the aperture angles of the pencils of rays passing through the individual lens elements are not too great, the light "traces" in the illuminated subject plane have a form similar to the form of the entrance pupils of the screen's lens elements. In any case determination of the form and position of these light "traces" represents no difficulty and can be performed by estimation of zero rays through various points in the entrance pupil of the lens element by the familiar equations in [3]. So, the size of the illuminated atea is then determined by the equation:

$$2y' = 2S' \operatorname{tg} u',$$

where S' is the distance from the equivalent rear plane of an optical system consisting of a collector and condenser to the subject illuminated.

It is obvious from fig 2 that $S' = S'_e + d_2$, where S'_e is the distance from the condenser to the equivalent rear focal point.

Table 1.

$D_p(x, y)$	(1) Упаковка	$U(x, y) \simeq F\{T(x, y)\}$
$\mathrm{rect}\left(\frac{x}{X}, \frac{y}{Y}\right)$	(2) Ортогональная	$\mathrm{rect}\left(-\frac{xf'_p}{Xf'_1}; -\frac{yf'_p}{Yf'_1}\right) \times \frac{\sin\left[\frac{kx}{f'_1}\left(N+\frac{1}{2}\right)X\right]\sin\left[\frac{yk}{f'_1}\left(M+\frac{1}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y}$
	(3) Треугольная	$\mathrm{rect}\left(-\frac{xf'_p}{Xf'_1}; -\frac{yf'_p}{Yf'_1}\right) \times \left\{\frac{\sin\left[\frac{kx}{f'_1}\left(2N+\frac{1}{2}\right)X\right]\sin\left[\frac{ky}{f'_1}\left(2M+\frac{1}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y} + \frac{\sin\left[\frac{kx}{f'_1}\left(2N+\frac{3}{2}\right)X\right]\sin\left[\frac{ky}{f'_1}\left(2M+\frac{3}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y}\right\}$
$\mathrm{circ}\frac{\sqrt{x^2+y^2}}{R}$	(2) Ортогональная	$\mathrm{circ}\left(\frac{f'_p}{f'_1}\frac{\sqrt{x^2+y^2}}{R}\right) \times \frac{\sin\left[\frac{kx}{f'_1}\left(N+\frac{1}{2}\right)X\right]\sin\left[\frac{ky}{f'_1}\left(M+\frac{1}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y}$
	(3) Треугольная	$\mathrm{circ}\left(\frac{f'_p}{f'_1}\frac{\sqrt{x^2+y^2}}{R}\right) \times \left\{\frac{\sin\left[\frac{kx}{f'_1}\left(2N+\frac{1}{2}\right)X\right]\sin\left[\frac{ky}{f'_1}\left(2M+\frac{1}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y} + \frac{\sin\left[\frac{kx}{f'_1}\left(2N+\frac{3}{2}\right)X\right]\sin\left[\frac{ky}{f'_1}\left(2M+\frac{3}{2}\right)Y\right]}{\sin\frac{kx}{2f'_1}X\sin\frac{ky}{2f'_1}Y}\right\}$

[Key on following page]

Table 1. [Continued]

$U(x, y) \simeq F\{F\{T(x, y)\}\}$
(2) $XY\frac{\lambda^2 f_1'^4}{f_p'^2}\sum_{n=-N}^{N}\sum_{m=-M}^{M}\mathrm{sinc}\left[\left(x+n\frac{f_2'}{f_1'}X\right)\frac{f_1'X}{\lambda f_p' f_2'};\ \left(y+m\frac{f_2'}{f_1'}Y\right)\frac{f_1'Y}{\lambda f_p' f_2'}\right]$
(3) $XY\frac{\lambda^2 f_1'^4}{f_p'^2}\sum_{n=-N}^{N}\sum_{m=-M}^{M}\left\{\mathrm{sinc}\left[\left(x+2n\frac{f_2'}{f_1'}X\right)\frac{f_1'X}{\lambda f_p' f_2'};\ \left(y+2m\frac{f_2'}{f_1'}Y\right)\frac{f_1'Y}{\lambda f_p' f_2'}\right]+ + \mathrm{sinc}\left[\left(x+(2n+1)\frac{f_2'}{f_1'}X\right)\frac{f_1'X}{\lambda f_p' f_2'};\ \left(y+(2m+1)\frac{f_2'}{f_1'}Y\right)\frac{f_1'Y}{\lambda f_p' f_2'}\right]\right\}$
(2) $\frac{R^2\lambda^2 f_2' f_1'}{f_p'^2}\sum_{n=-N}^{N}\sum_{m=-M}^{M}\frac{I_1\left[\frac{kf_1'R}{f_2'f_p'}\sqrt{\left(x+n\frac{f_2'}{f_1'}X\right)^2+\left(y+m\frac{f_2'}{f_1'}Y\right)^2}\right]}{\sqrt{\left(x+n\frac{f_2'}{f_1'}X\right)^2+\left(y+m\frac{f_2'}{f_1'}Y\right)^2}}$
(3) $\frac{R^2\lambda^2 f_2' f_1'^4}{f_p'^2}\sum_{n=-N}^{N}\sum_{m=-M}^{M}\left\{\frac{I_1\left[\frac{kf_1'R}{f_2'f_p'}\sqrt{\left(x+2n\frac{f_2'}{f_1'}X\right)^2+\left(y+2m\frac{f_2'}{f_1'}Y\right)^2}\right]}{\sqrt{\left(x+2n\frac{f_2'}{f_1'}X\right)^2+\left(y+2m\frac{f_2'}{f_1'}Y\right)^2}}+ + \frac{I_1\left[\frac{kf_1'R}{f_2'f_p'}\sqrt{\left(x+(2n+1)\frac{f_2'}{f_1'}X\right)^2+\left(y+(2m+1)\frac{f_2'}{f_1'}Y\right)^2}\right]}{\sqrt{\left(x+(2n+1)\frac{f_2'}{f_1'}X\right)^2+\left(y+(2m+1)\frac{f_2'}{f_1'}Y\right)^2}}\right\}$

Key:

1. Packing
2. Orthogonal
3. Triangular

We know from [3] that:

$$S'_э = \frac{1-\varphi_1 d_1}{\varphi_э} \text{ и } \varphi_э = \varphi_1 + \varphi_2 - \varphi_1\varphi_2 d_1,$$

where ϕ_e, ϕ_1 and ϕ_2 are the optical strengths of the equivalent optical system, the collector and condenser, respectively, and d_1 is the distance between the collector and condenser.

As in the previous case, the size of the illuminated area depends on the aperture of the screen's lens element. In determining the distribution of intensity in the illuminated area, we assume for simplicity that $d_1 = f_1'$ and $d_2 = f_2'$, where f_1' and f_2' are the focal lengths of the collector and condenser.

Obviously, the distribution function for the amplitude field, U(x,y), in the illuminated area is determined thus:

$$U(x, y) \simeq F\{F\{T(x, y)\}\},$$

and, consequently,

$$U(x, y) \simeq F\{F\{T_p(x, y)\}\} * F\{F\{L(x, y)\}\},$$

where the symbol * indicates the contraction operation.

The final result for U(x,y), as previously, is reduced to a table, from which it is obvious that the maximum values of space frequency for a single term of bivariate sums can be determined from the following equations:

$$\nu_x = \frac{f_1'}{f_2'} \cdot \frac{X}{2\lambda f_p'}, \quad \nu_y = \frac{f_1'}{f_2'} \cdot \frac{Y}{2f_p'\lambda},$$

where ν_x and ν_y are space frequencies along the X and Y axis.

As a result of the overlapping of light "traces" which are shifted relative to one another, the interference pattern becomes more complex. By altering f_1', f_2' and u', it is possible to achieve matching of the frequency of this interference pattern with the required resolution of the optical system constructing an image of the illuminated subject. It is obvious that in this case it is possible to obtain a higher frequency of succession of interference pattern maxima than in the first of the cases considered.

This design technique has been applied in developing illuminating devices for a piece of equipment operating according to the phototelegraphy method, and for a microscope. The optical systems of these illuminating devices were constructed according to the arrangement shown in fig 2. In these were employed lens screens with a numerical aperture of A = 0.11 and a spacing of 0.17 mm, and the focal length of the collector was selected as 8 mm, and of

the condenser as 16 mm. An LG-56 (λ = 632.8 nm) gas laser was used as the light source. Let us determine the value of the resolution of the optical system, ν, constructing an image of the subject illuminated by this illuminating device, by the equation given above. It is obvious [4] that $\nu \leq 870\ mm^{-1}$.

If there were no collector in the device, then the following inequality would hold true for ν:

$$\nu \leqslant 170\ \text{мм}^{-1}.$$

From this it is possible to conclude that, for systems with high required resolution, it is advisable to implement the illuminating device according to the second arrangement, and for systems with not too high resolution but with high required illuminance of the subject (e.g., a phototelegraphic apparatus), it is advisable to make the illuminating device according to the first arrangement. Tests of these illuminating devices in equipment for automatic conversion of oscillograms on photographic paper have demonstrated that the measured subject contrast, equaling 0.15 to 0.2 with incoherent illumination, increased to 0.3 to 0.5. A visual evaluation of the graininess of the image obtained shows a considerable reduction in it. Mention should be made in conclusion of the fact that the requirements for the quality of an image created by a collector and condenser are the same as for ordinary illuminating devices.

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ENGINEERING AND EQUIPMENT

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TWO-CHANNEL HIGH-SPEED DRIVE FOR AN OPTICAL SIGHTING DEVICE, OPERATING UNDER CONDITIONS OF A RANDOM MOMENT OF LOAD ON THE OUTPUT SHAFT

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY, PRIBOROSTROYENIYE in Russian Vol 21 No 6, pp 101-105 manuscript received 9 Jun 77

[Article by I.T. Tarasova, V.A. Kudryavtsev and M.A. Pakkanen, Leningrad Institute of Precision Mechanics and Optics]

[Text] Discussed here is a unified follow-up system of the "speed-speed" type, used to control the speed of a drive for an optical sighting device. Equations are given for the rotational velocity of the drive's output shaft and a determination is made of the conditions for invariance of the speed in relation to the moment of load. An experimental investigation is made of a model of a two-channel high-speed drive (DSP) under conditions of a random static moment of load on the output shaft.

A distinctive feature of controlling the rotational velocity of an optical sighting device consists in the necessity of matching the drive's dynamics with the requirements for the resolving power of the drive as a whole. The requirements for smooth motion of the drive's output shaft increase especially with high magnification. Here the instrument's output shaft moves at a slow, sometimes "creeping" rate, whereby the moment of load is of an uneven, random nature. An ordinary single-motor control system requires under these conditions a high gain, and, consequently, complex dynamic compensation. As is demonstrated below, partial invariance of the speed of the drive's output shaft in relation to the moment of load on the shaft is achieved considerably more simply in a two-motor system.

This article is devoted to a description of the results of theoretical and experimental investigations of a DSP when it operates under conditions of a random static load on the output shaft of the optical sighting device's drive.

A structural diagram of the drive is shown in fig 1, where U_{ykh} is the control voltage, $k_{dv1}(p)$ and $k_{dv2}(p)$ are transfer functions in terms of the speed of motors of the first and second channel, i_1 and i_2 are the

transmission ratios of the reducers, whereby $i_1 > i_2$, ω_1 and ω_2 are the angular velocities of the motors' shafts, ω_3 is the angular velocity of the differential's output shaft, β_1 and β_2 are the tachometric coupling factors of the first and second channel, k_s is the channel coupling factor, U_1 and U_2 are control voltages for the channels' motors, and M_{n1} and M_{n2} are the moments of load of the first and second channels brought to the motors' shafts. A similar arrangement was discussed in [1]. The difference in this arrangement from that suggested in [1] consists in the absence of a high-speed differential, whose manufacture and adjustment presents considerable difficulties. Here channels are coupled electrically via a transmission with a factor of k_s, and speeds are integrated in an ordinary non-high-speed planetary differential.

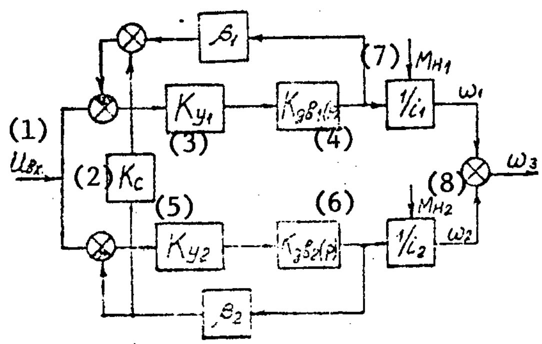

Figure 1.

Key:

1. U_{vkh}
2. k_s
3. k_{u1} [gain, channel 1]
4. $k_{dv1}(p)$
5. k_{u2} [gain, channel 2]
6. $k_{dv2}(p)$
7. M_{n1}
8. M_{n2}

Let us determine the values of speeds ω_1 and ω_2 as a function of the input signal, U_{vkh}, and the values of moments of load M_{n1} and M_{n2}. Taking into account the fact that

$$\omega_1 = k_{\text{дв}1}\left(U_1 - \frac{R_{\text{я}1}M_{\text{н}1}}{k_{\text{м}1}}\right), \quad \omega_2 = k_{\text{дв}2}\left(U_2 - \frac{R_{\text{я}2}M_{\text{н}2}}{k_{\text{м}2}}\right), \tag{1}$$

where, according to the structural diagram,

$$U_1 = k_{\text{у}1}(U_{\text{вх}} - \beta_1\omega_1 - k_c\beta_2\omega_2), \quad U_2 = k_{\text{у}2}(U_{\text{вх}} - \beta_2\omega_2), \tag{2}$$

we write the values of steady-state speeds ω_1 and ω_2 :

$$\omega_1 = \frac{U_{\text{вх}}}{\beta_1}(1 - k_c) + \frac{\beta_2 k_c}{\beta_1 k_2}\omega_{\text{н}2} - \frac{\omega_{\text{н}1}}{k_1}, \quad \omega_2 = \frac{U_{\text{вх}}}{\beta_2} - \frac{\omega_{\text{н}2}}{k_2}. \tag{3}$$

The following symbols are introduced in equations (1) to (3): k_{dv1} and k_{dv2} are the transmission coefficients of the motors in terms of speed, R_{ya1} and R_{ya2} are the resistances of the motors' armature windings, k_{M1} and k_{M2} are factors for the slope of the electromechanical characteristics of the motors, k_{u1} and k_{u2} are the gain of the amplifiers, $k_1 = \beta_1 k_{dv1} k_{u1}$ and $k_2 = \beta_2 k_{dv2} k_{u2}$, and $\omega_{n1} = (k_{dv1} R_{ya1}/k_{M1}) M_{n1}$ and $\omega_{n2} = (k_{dv2} R_{ya2}/k_{M2}) M_{n2}$ are the values of the pickup speeds of the motors, corresponding to moments of friction M_{n1} and M_{n2}. Equations (3) hold true when $U_{vkh}/\beta_2 > \omega_{n2}/k_2$, i.e., until the motor of the second channel stops. When $U_{vkh}/\beta_2 \leq \omega_{n2}/k_2$ and in the case when the second channel's motor goes out of order for some reason or other, the speed equations take the following form:

$$\omega_1 \simeq \frac{U_{\text{вх}}}{\beta_1} - \frac{\omega_{\text{н}1}}{k_1}, \quad \omega_2 = 0. \tag{4}$$

In the first case, according to equations (3), the first channel is the compensating channel and works off the error of the second channel with a degree of accuracy up to its own error, equal to ω_{n1}/k_1. In the second case, according to equations (4), the first channel operates independently, having a maximum speed of $\omega_{max} \simeq U_{vkh\ max}/\beta_1$, where $U_{vkh\ max}$ is the maximum value of the input control voltage, and a minimum speed of $\omega_{min} \geq \omega_{n1}/k_1$, whence the range of controllable speeds of a single-channel drive is $D_1 \simeq U_{vkh}\ max/ /\beta_1\omega_{n1}$. Further, in the first case the value of the steady-state speed of the differential's output shaft is determined by the equation:

$$\omega_3 = \left(\frac{1 - k_c}{\beta_1 i_1} + \frac{1}{\beta_2 i_2}\right) U_{\text{вх}} - \left(\frac{1}{i_2} - \frac{k_c\beta_2}{i_1\beta_1}\right)\frac{\omega_{\text{н}2}}{k_2} - \frac{\omega_{\text{н}1}}{i_1 k_1}, \tag{5}$$

from which it is obvious that when $k_s\beta_2/\beta_1 = i_1/i_2$ the value of the steady-state speed of the differential's output shaft does not depend on the value of the moment of friction on the drive's shaft. Then,

$$\omega_3 \simeq \frac{U_{\text{вх}}}{\beta_2 i_2} - \frac{\omega_{\text{н}1}}{i_1 k_1}, \tag{6}$$

from which a determination is made of the range of controllable speeds, D_2, of a two-channel drive:

$$\omega_{3\,max} = \frac{U_{вх\,max}}{\beta_2 i_2}; \quad \omega_{3\,min} \geqslant \frac{\omega_{н1}}{i_1 k_1}, \text{ i.e., } D_2 = \frac{U_{вх} k_1 i_1}{\beta_2 \omega_{н2} i_2}. \tag{7}$$

As is obvious from equations (4) and (7), the range of controllable speeds of a DSP grows by a factor of i_1/i_2.

Thus, it has been demonstrated that, because of the compensating effect of the first channel, in a DSP partial invariance of the regulation system is made possible in relation to the moment of load, which results in smoother and more precise speed regulation. This has been confirmed by an experimental investigation of a model of a drive. In this model were employed two DPR type d.c. motors of identical output, connected to the load via 2K-N type unified reducing devices (URU's) [2]. Two identical type TGP-3 d.c. tachogenerators were used as sensing devices for the angular velocity of the motors' shafts. The moment of load was simulated by a special circuit. In constructing this circuit the materials in [3] were used. A structural diagram of the load model is shown in fig 2. A low-frequency noise signal from a noise generator, GSh, after smoothing in an RC network and amplification in an amplifier, U_1, arrives at a switch, K, which periodically, at frequencies of 1, 2, 5 or 10 Hz, admits the signal to an integrator, I. After amplification in a power amplifier, U_2, the signal inundates the armature winding of a motor, D, which is connected via a coupling to the output shaft of the DSP's differential. An oscillogram of the motor's current is shown in fig 3a.

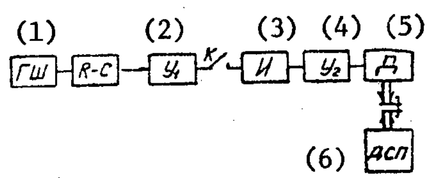

Figure 2.

Key:

1. GSh
2. U_1
3. I
4. U_2
5. D
6. DSP

Test Results

Tests of a DSP model under conditions of an external static load of a random nature have demonstrated its considerable advantages over a one-motor system. In fig 3 are shown oscillograms for processing of a sinusoidal input signal by a DSP (fig 3b) and a single-motor system (fig 3c) when a random static moment of load acts on the drive's output shaft.

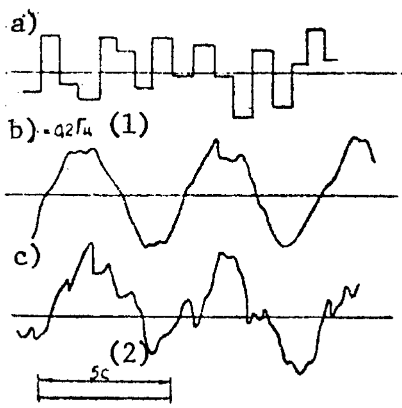

Figure 3.

Key:

1. f = 0.2 Hz
2. 5 s

The smoother and more precise processing of the input signal in the DSP is explained by partial invariance of the output shaft's speed in relation to the moment of load, which is made possible by the first channel. To illustrate the compensating effect of the first channel, in fig 4 are shown oscillograms for processing of a sinusoidal input signal by this channel in the absence of an external load (fig 4a) and when one is at work (fig 4b).

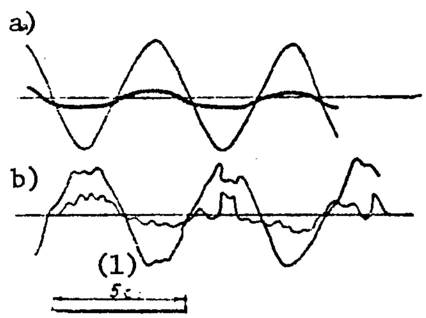

Figure 4.

Key:

1. 5 s

Theoretical and experimental investigations have shown that a DSP makes it possible to obtain a wide range of controllable speeds without imposing the

requirement of high gain, which considerably simplifies dynamic synthesis of the system. In a DSP the required range of controllable speeds is achieved by a simple selection of parameters (ratio i_1/i_2). The unevenness of the static load has almost no influence on the smoothness of the controllable speeds. It is advisable to employ a DSP under conditions of a moment of friction on the output shaft of a random nature and when smooth motion of the optical instrument's output shaft is required.

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ENGINEERING AND EQUIPMENT

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FUNCTIONAL RELATIONSHIP OF ANGULAR ABERRATIONS FOR SYSTEMS WITH INHOMOGENEOUS MEDIA

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[Article by Yu.F. Yurchenko, Krasnogorsk]

[Text] Discussed here is the relationship between total aberration and angular aberrations occurring on the surfaces of an optical system with variable refractive indices.

With a sufficient degree of accuracy it can be assumed that the angular divergence occurring on refracting surfaces is maintained when a beam moves in an inhomogeneous medium. A precise determination of the relationship between the angular divergence of beams and their path in an inhomogeneous medium has been hampered because of the absence of an analytical solution to the beam path equation.

The equation for the path of a beam in a certain section of the meridian plane can be represented approximately in the form of a truncated Taylor expansion:

$$y = y_0 + y_0' x + \frac{y_0'' x^2}{2}, \tag{1}$$

where $x_0 = 0$ and y_0, y_0' and y_0'' are parameters of the beam path at the original point of the section.

For a medium with a cylindrical distribution of the refractive index of the form $n = n_0 + ky^2$ [1],

$$y'' = \frac{2ky\,(1 + y'^2)}{n}. \tag{2}$$

From (1) it follows that:

$$y' = y_0' + y_0'' x. \tag{3}$$

The differential of function y' when y'_0 varies is

$$dy' = dy'_0 + x\frac{\partial y''_0}{\partial y'_0}; \quad \frac{\partial y''_0}{\partial y'_0} = \frac{4ky_0y'_0}{n} = A. \tag{4}$$

If the angular divergence at point x_0, y_0 equals Δ_0 (fig 1), then

$$\Delta_0 = \operatorname{arctg} \bar{y}_0' - \operatorname{arctg} y_0' \ll 1, \tag{5}$$

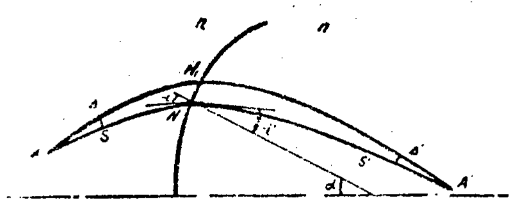

Figure 1.

and if allowance is made for the fact that $y'_0 \approx \bar{y}'_0$, then

$$\operatorname{tg} \Delta_0 = \frac{\bar{y}'_0 - y'_0}{1 + y'_0\bar{y}'_0} = \frac{\delta y'_0}{1 + y'^2_0}; \tag{6}$$

and at point M (x_m, y_m):

$$y_m' = y_0' + y_0'' x_m, \tag{7}$$

$$\operatorname{tg} \Delta_m = \frac{\delta y'_m}{1 + y'_m\bar{y}'_m} = \frac{\delta y'_m}{1 + y'_m(y'_m + \delta y'_m)}. \tag{8}$$

It follows from (4) that

$$\delta y_m' \cong \delta y_0'(1 + x_m A), \tag{9}$$

Then, taking (5) and (6) into account, we get

$$\operatorname{tg} \Delta_m = \frac{\delta y'_0(1 + x_m A)}{1 + y'^2_m + y'_m\delta y'_0(1 + x_m A)} = \frac{\delta y'_0(1 + x_m A)(1 + y'^2_0)}{(1 + y'^2_0)(1 + y'^2_m)} = p \operatorname{tg} \Delta_0, \tag{10}$$

where

$$p = \frac{(1 + x_m A)(1 + y_0'^2)}{(1 + y_m'^2)}.$$

(11)

If it is assumed that $y'_m - y'_0 = 0.1$ when $x = 50$ mm and $y_0 \leq 1$, (which corresponds approximately to deflection of the beam path by three to six degrees), and $y = 100$ mm and $n_{max} = 2$, then from (7) and (2)

$$y'_m - y'_0 = y''_0 x_m = \frac{2ky_0(1 + y_0'^2)}{n} x,$$

(12)

from which

$$K_{max} = \frac{(y'_m - y'_0)\, n_{max}}{2y_0(1 + y_0'^2)\, x_m} = 0{,}1_{10} - 4$$

(13)

and $P = 0.9858 \approx 1$, i.e., $\tan \Delta_0 \approx \tan \Delta_m$. The values of P under other conditions will also approach unity.

When the beam moves in an inhomogeneous medium the angular divergence is kept similar to the angular divergence in a homogeneous medium. Then the invariant from [2] can be written thus:

$$\frac{S\Delta}{S'\Delta'} = \frac{\cos i}{\cos i'},$$

(14)

where S and S' are beam paths in inhomogeneous media cn and n'. Segments t and t' of the astigmatic invariant

$$\frac{n' \cos^2 i'}{t'} - \frac{n \cos^2 i}{t} = \frac{n' \cos i' - n \cos i}{r}$$

(15)

will equal: $t = S$ and $t' = S'$.

The functional relationship of (25) from [2] can be written thus:

$$\sum_{k=1}^{n} \Delta g'_k = \Delta_n L'_n + \sum_{1}^{n-1} \Delta_k W'_{tk}(L'_n - t^n_k),$$

(16)

where W'_{tk} is the angular value for the k-th surface and n is the number of surfaces;

$$W'_{tk} = -\frac{\bar{d}_k}{t_k^{k+1}} \cdot \frac{\cos i'_{k+1}}{\cos i_{k+1}} \cdot \prod_{p=k+1}^{n-1} \left[\frac{\left(t_k^p - \bar{d}_p\right)}{t_k^{p+1}} \cdot \frac{\cos i'_{p+1}}{\cos i_{p+1}} \right]; \tag{17}$$

Δ_k is the angular aberration from the k-th surface (fig 2); d_k is the oblique depth between surfaces k and $k+1$ along the beam path; t_k^p is the distance from the p-th surface to the astigmatic image of the k-th surface along the beam path; i_k and i'_k are the angles of incidence and refraction of the beam on these surfaces; and $\Delta q'_k$ is the lateral aberration introduced by each surface.

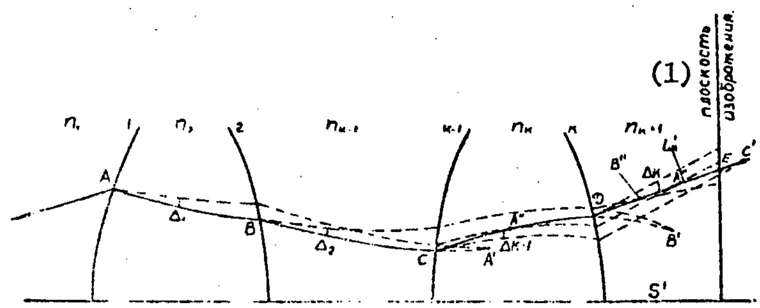

Figure 2.

Key:
1. Image plane

Thus, utilizing the conditions for maintenance of the angular divergence of beams during motion of a beam in an inhomogeneous medium, it is possible to break down the total aberration in the image plane into individual aberrations contributed by each surface.

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BIOLOGICAL EXPERIMENTS ON BOARD 'SALYUT-6'

Moscow TEKHNIKA-MOLODEZHI in Russian No 6, 1978 pp 12-13

[Article by Aleksandr Kamin, Candidate Biological Sciences: "Gravitation and Life"]

[Text] During one of the televised sessions with the "Salyut-6" station, "Taymyr-1" -- this was the call-sign of the crew commander Yuriy Romaneko -- reported: "A few days ago, while observing the earth, we suddenly discovered a fly on the window. It was small, pretty and very unusual with golden wings. At first we were very glad, but later, after seeing a second one, we were surprised. And when a third appeared, it became clear to us that it was no wonder for apparently some kind of malfunction had arisen in the system in which the fruit fly biological experiment was being conducted."

The cosmonauts questioned the ground concerning the possible reasons for the malfunction and soon received an answer: "The flies were flying out through the air duct."

"We must do something," said Georgiy Grechko, "so that the wolves will be full and the flies whole."

The "Taymyrs" spent several days catching the flies, but did not terminate the important biological experiment, which was one of several being performed during December-March of this year on board the "Salyut-6" station.

Being located in orbital flight, the space station permitted scientists to set up unique experiments which were impossible under earth's conditions -- to study the influence of gravity on the evolution of living organisms. This is why biological experiments have already long occupied a significant place in the flight programs of several orbital stations.

It is customary to assume that inside such a station complete weightlessness reigns. But in fact this is not so. Aerodynamic braking in the rarified upper layers of the atmosphere, light pressure and other forces exert a small, though noticeable effect. Besides these external forces, internal perturbing forces also affect the station: maneuvers and orbital corrections, impacts during the dockings, movements about and training by the crew, and local gravitation created by mutual attraction of the station's separate masses.

Of course, these G-forces are not large -- totalling $10^{-5} \div 2 \cdot 10^{-2}$g -- they are oriented in different directions and at different times, and still even they influence the development of living organisms. For example, the likely threshhold value for plant shoots amounts to $1.4 \cdot 10^{-3}$g, and for the roots -- 10^{-3} - 10^{-4}g. The threshhold for the gravitational sensitivity of small-sized vertebrates and non-vertebrate organisms, apparently, amounts to nearly 10^{-3}g. Thus, the study of the influence of weightlessness on organisms on board an orbital station requires the creation of instruments and facilities in which even such insignificant loads have been compensated for.

This is why on "Soyuz-22", piloted by V. Bykovskiy and V. Aksenov, an experiment with corn seedlings was conducted in the "Biogravitat" instrument, with the aid of which it was possible to show: under G-load damping the seedlings develop much more slowly. This result, which shows that weightlessness adversely affects the growth of higher plants, was an important addition to the first experiments on the physiology of plants which were performed on Soviet and American spacecraft.

These experiments showed that short duration space flight did not retard the germination of wheat and pea seeds, or the initial growth of the seedlings. The structure of the basic organs, tissues and cells was not significantly changed, and the levels of mutations (changes) and chromosome aberrations did not increase. However, several changes did arise; the spatial orientation of the seedlings, their leaves and roots was disrupted. The activity of several enzymes and the intensity of their respiration was changed. The cells of the wheat roots divided more slowly, but then they lengthened more quickly than those of the control plants on the ground. The number of nuclei with broken shafts, as well as the number of multinuclear cells, increased in the Tradescantia microspores within the cells of the embryonic follicles and tips of its roots. In the peas, the number of binuclear cells increased and trinuclear cells appeared. All this attested to the destruction of the cell division processes under conditions of weightlessness.

Why do stems grow upwards, but roots stretch downwards? Where, in what part of the growth cells is the apparatus for the gravitational formula hidden? According to one hypothesis, the secret of geotropism is hidden within statoliths -- small granules of starch located within the cells. Under the influence of gravity, the statoliths seemingly sink to the lower cellular membranes and become the centers for biochemical reactions, in which, in particular, the growth stimulant molecules are synthesized -- indolyl acetic acid, which determines the direction of growth.

Under weightless conditions, the statoliths are distributed uniformly throughout the entire volume of the cellular cytoplasm. They do not press against the lower membranes and it is precisely here that they do not promote the development of growth stimulants. It is possible, just because of this that spatial disorientation and the destruction of cytogenesis emerges: upon attaining a specific growth development stage the peas begin to die.

It is even possible to show how this occurs. A reduction in the indolyl acetic acid content results in a change of the cells ionic composition. Potassium and calcium ions separate out from the cell. And with the reduction of the content of these ions within the cells of the stomata which results in the destruction of the gaseous and water exchange processes, the plant perishes.

How then do other organisms behave themselves, while actively developing under conditons of space flight? We have already written about hydrogenous bacteria (TEKHNIKA -- MOLODEZHI, No 4, 1974). Their growth was even better than on earth: under conditions of weightlessness there was no cellular precipitation, they were constantly in a suspended state, therefore the conditions of their gaseous-mineral feeding in weightlessness was better than on earth.

Chlorella is not a novice in orbit: it has already been exhibited on "Kosmos-573", on the "Soyuz-13" spacecraft and on other space apparatuses. The interest of scientists in this microscopic algae is not accidental: chlorella is one of the best biological specimens for research in space. It is easy to grow; it is not difficult to obtain from it a cellular population which is located at a single stage; and the presence of a differentiated nucleus brings it closer to higher organisms.

On board "Salyut-6", with the aid of chlorella, it was decided to study the occurrence of delicate processes outside the earth in order to establish a "point of reference" for the operating factors in extended flight. For these investigations an instrument was developed which permitted the placing in orbit of a microorganism in a state of anabiosis. The very first results showed that the cellular growth of chlorella in weightlessness was significantly more intensive than on earth.

The Soviet-French experiment "Cytos" was conducted on equipment developed by French and Soviet specialists. Its purpose is to study the kinetics of cellular division in the simplest life forms and microorganisms. For the experiments, the French chose the Infusoria-paramecium, a one-celled organism well-studied and well-known to all students. Our scientists made their selection on a common microorganism, Proteus, capable of existing within a wide temperature range.

The live specimens in this experiment were placed in polyethylene inserts -- Berlingo -- with a feeding medium and a fixative ampoule. The Berlingo is made up of 8 sections, each with 20 specimens. The entire assembly was placed in a lined container which was delivered in the Soviet "Bioterm"

incubator at a temperature of $+8^0$ C on board the "Salyut-6" scientific station by a visiting expedition. At this temperature active growth of the organisms does not occur. Immediately after docking, the container with the Berlingo was transferred to the French "Cytos" instrument which was installed on board "Salyut-6". Within the instrument the temperature was $+25^0$ C. This is a thermal optimum for both types of organisms. Every 12 hours, G. Grechko activated the fixator power unit within the instrument and in all the Berlingos of one section, the fixator ampoules were broken. Altogether during the expedition eight fixations were performed, after which the insert with the experimental material was returned to earth.

At the end of the experiment, Georgiy Grechko made a detailed report concerning its conduct. In practice the cosmonauts were creative participants in all the biological experiments on board "Salyut-6". They not only pedantically reported on their own activities, but also required feed back from the ground: "We want to know the results of the experiments," reported the "Taymyrs" to the ground. "Then it is more interesting for us to work with the equipment and instruments."

In spite of the fact that several fruit flies managed to get out of the instrument, the experiments with them were completed successfully. This little fly is distributed throughout the entire earth and feeds on the juices of berries and fruits. One of its most important characteristics for science is its rapid propagation rate: its entire development cycle takes 10 - 12 days. Within a day after the female lays its eggs, the larvae hatch, within 5 - 6 days they pupate, and by the 10th - 12th day there appear adult insects capable of reproduction.

The mechanisms of origination and inheritance of diverse changes, which allows for the study of the influence of various factors, is well examined with the fruit flies.

And there is still another model specimen located on board "Salyut-6" -- the roe of amphibians. If quite a lot is already known concerning the geotropism of plants, then significantly less is known concerning the influences of the force of gravity on the embryonic development processes of animals. The ordering of division, which leads to the formation of an organism, and not a formless mass of cells, is possibly regulated by the force of gravity.

For the solution of these questions there was also performed an experiment with frog eggs which were fertilized just before the launch. They were placed in the "Emkon-T" (embryological temperature-controlled container).

Studying the behaviour of an organism under conditons of weightlessness provides a key to understanding the role of gravitation in the evolution of life. Why even throughout geological history the force of gravity on earth has not remained constant, but periodically has changed depending on the position of our planet within its galactic orbit.

Several scientists connect the key evolutionary events with the periodic changes in the force of gravity. Thus during an epoch of gravitational reduction living creatures left the water for the dry land (the end of the Devonian Period), and raised themselves into the air (Jurassic Period). According to one hypothesis, the extinction of the gigantic reptiles -- ichthyosaur, dynosaurs, and pterodactyls -- coincides with a phase of gravitational increase. And now the largest animals may live only in the ocean.

Biological experiments in orbit promise to provide a key also to the solution of one important purely physical problem. They make it possible to verify the equivalency of forces principle, in accordance with which the force of inertia, in particular, is equal to the gravitational force. It is specifically thanks to the principle of equivalence on space ships that one may create an artificial gravity with the assistance of equipment which provides a constant acceleration acting on the test object. The simplest of these devices is the centrifuge, where the force of gravity is replaced by centripetal force. For this reason, in the evolution of living organisms placed under condition of artificial gravity in an orbital space ship, there also lies the guarded deciding experiment on the basic postulate of the general theory of relativity. If the evolution of such microbes is going differ from the evolution of control organisms on earth, then as it applies to biological specimens the principle of equivalency is wrong!

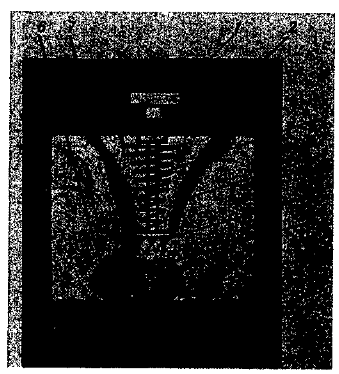


Figure 1. Instrument for the "Chlorella" Experiment

The instrument (1) consists of a housing (2) with tranparent hydrophilic walls from within. On the outside, there is a striker handle, and on the inside a spring (3) and a protective rubber hood (4). The striker terminates in a thrust head (5) for smashing the ampoules. At the bottom of the instrument, there are fastened a shell (6) with chlorella, a shell (7) with the fixative, a shell (8) with an active physiological agent, a shell (9) with the "marker", and (10) the food medium. By means of the striker, the cosmonauts may break any shell in conformance with the experimental program.

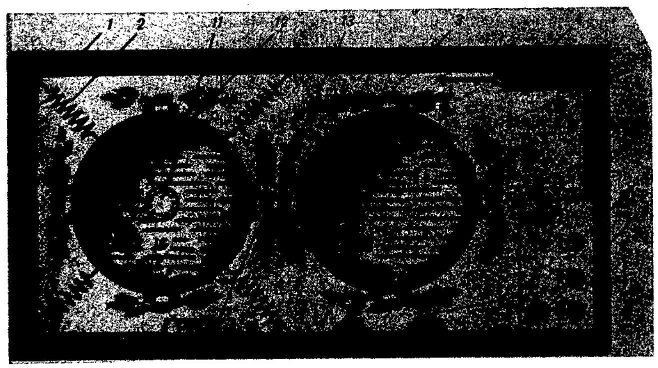


Figure 2. "Biogravitat"

Within the housing of the instrument (1) there are located two seed containers. Seed container A is rigidly attached by a pedestal (10) to the housing of the instrument. Seed container B is dampened from external influences by means of resilient springs. An arresting device (11) holds the seed container during the launching of the spacecraft. The seeds (3) are attached to the housing. The water injector (4) is intended to perform a single watering through the aperature (5). Within the instrument there are two injectors for each seed container. The recording device is (6). The digital G-load indicator is (7). The G-load level button is (8). Within the instrument there are three G-load levels: I -10^{-1} -10^{-2}g; II -10^{-2} -10^{-3}g; and III -10^{-3} -10^{-5}g. The number of recorded perturbations for each level lights up on the digital indicator. The reset button is (9). The nourishment substrate is (12). The G-load seismic sensor is (13). In the orbit of an artificial earth satellite, the nourishment substrate is moistened and the seeds begin to germinate. Following this seed container B is freed. The seed containers are covered with a lightproof casing.

Within the housing of the fruit fly experiment (2) there is an opening for air (1), connected through the capillary air ducts with the chambers in which the nutritive medium (4) is located. The housing is divided into two chambers, A and B, which can be connected to one another with the aid moveable shutters (3). On the ground before beginning the experiment, they placed male and female fruit flies in chamber A. The females laid eggs, following which they extracted the adult insects from the chamber. The little home is also set up as an incubator. Within chamber A the eggs become larvae (5), which feed on the nutrituve medium and then pupate. From the pupae fly grown insects (8), which fly across through the open shutter (9) to the fresh nutritive medium in chamber B and lay eggs (7).

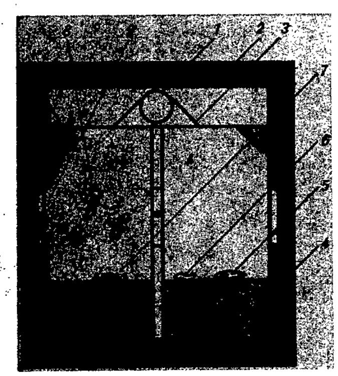
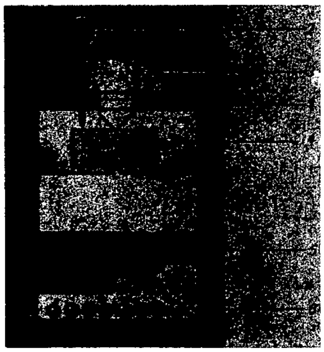


Figure 3.

Operational Diagram of the Home for Fruit Flies



Within the housing of the instrument (1) water (5) is poured and an impregnated egg (6) is placed. The instrument is fitted out as an incubator. According to the experimental program the cosmonaut, with the aid of a screw (3), and having removed the arresting device (2), splits open the flask with the fixative (4).

Figure 4. "Emkon-T"

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PULSATIONS AND EXPANSION OF THE EARTH -- A POSSIBLE KEY TO AN UNDERSTANDING OF ITS TECTONIC DEVELOPMENT AND VOLCANISM IN THE PHANEROZOIC[1]

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[Article by Ye. Ye. Milanovskiy]

[Text] Yevgeniy Yevgen'yevich Milanovskiy, associate member of the Soviet Academy of Sciences, chief of the department of historical and regional geology of Moscow State University imeni M. V. Lomonosov. Deals with problems of regional tectonics, neotectonics and volcanism of geosynclinal and rift regions. Investigator of the geology of the Caucasus and other mountainous territories of the Alpine Belt and the rift zones of East Africa and Iceland. The author of numerous scientific papers including monographs: "Noveyshaya tektonika Kavkaza" [Recent Tectonics of the Caucasus], Moscow, 1968; "Orogennyy vulkanizm i tektonika Al'piyskogo poyasa Yevrazii" [Orogenic Volcanism and Tectonics of the Alpine Belt of Eurasia] (co-author N. V. Koronovskiy), Moscow, 1973; "Vostochno-Afrikanskaya riftovaya sistema" [The East African Rift System] (co-authors V. V. Belousov et al.), Moscow, 1974; "Riftovyye zony kontinentov" [Rift Zones of the Continents], Moscow, 1976; "Islandiya i Sredinno-Okeanskiy khrebet" [Iceland and the Mid-Ocean Mountain Chain] (co-authors V. V. Belousov et al.), Moscow, 1978 and others. Has published an article in *Priroda*, "Atlantis in the Aegean Sea?" (1969, No 1).

NEW DATA ON THE STRUCTURE OF THE EARTH, AND THE CONCEPT OF PLATE TECTONICS

The breadth and depth of our knowledge on the structure and development of the earth have increased immeasurably in the decades following the War. The investigation of the geology of the oceans has led to the discovery of enormous mid-ocean mountain chains and accompanying rift valleys that form a world-wide rift system together with the rift zones of the continents that we have known about for a long time. It has become clear that alongside the

geosynclinal belts -- the principal zones of subduction and periodic crumpling of the earth's crust -- there exists another type of belt with high tectonic and magmatic activity similar to the geosynclinal belts in overall extent and area, but sharply different in predominating kinematic tendencies -- elevation of material from the depths and horizontal spreading.

It has been established that structures related to certain types of recent continental rift zones had already arisen in the late pre-Cambrian, while all the other known types of rift structures on earth developed during the Mesozoic and Cenozoic. In the oceanic rift ridges and over extensive areas of the adjacent ocean bed the geomagnetic field has shown a stripe-like structure unlike that of the continents. Drilling has revealed that underlying the sediments on the ocean floor everywhere are Jurassic, Cretaceous or Cenozoic basalts, the most recent of which emerge on the ocean bottom in the axial zones of rift ridges. It has been established that the earth's crust beneath the continents and oceans differs sharply in structure and thickness. Over the greater part of the earth's surface in the upper mantle a layer has been detected that is distinguished by a relatively low rate of transmission of seismic waves, and consequently by low viscosity and density of the material that comprises it. This relatively "softened" and loosened layer (the asthenosphere) has been found to be thicker and more clearly defined beneath the oceans as well as under moving zones of the continents.

It has been proved that groups of ultramafic and mafic rocks of complicated structure that are present in many geosynclinal belts -- what we call ophiolilitic suites -- are remnants of an oceanic type of crust that once existed in the eugeosynclinal zones of these belts at an early age of their development, and has since been squeezed, crushed and pushed out into nearby tectonic zones.

The latest studies of many folded regions have shown that they have extensive tectonic sheaths about which even recently there was considerable doubt; these studies have renewed or reinforced notions of considerable horizontal contraction (compression) of zones of this kind. Paleomagnetic research results have brought many investigators to the conclusion that during the Phanerozoic Era large blocks of the earth's crust have changed their relative positions and also their positions with respect to the magnetic axis of the earth.

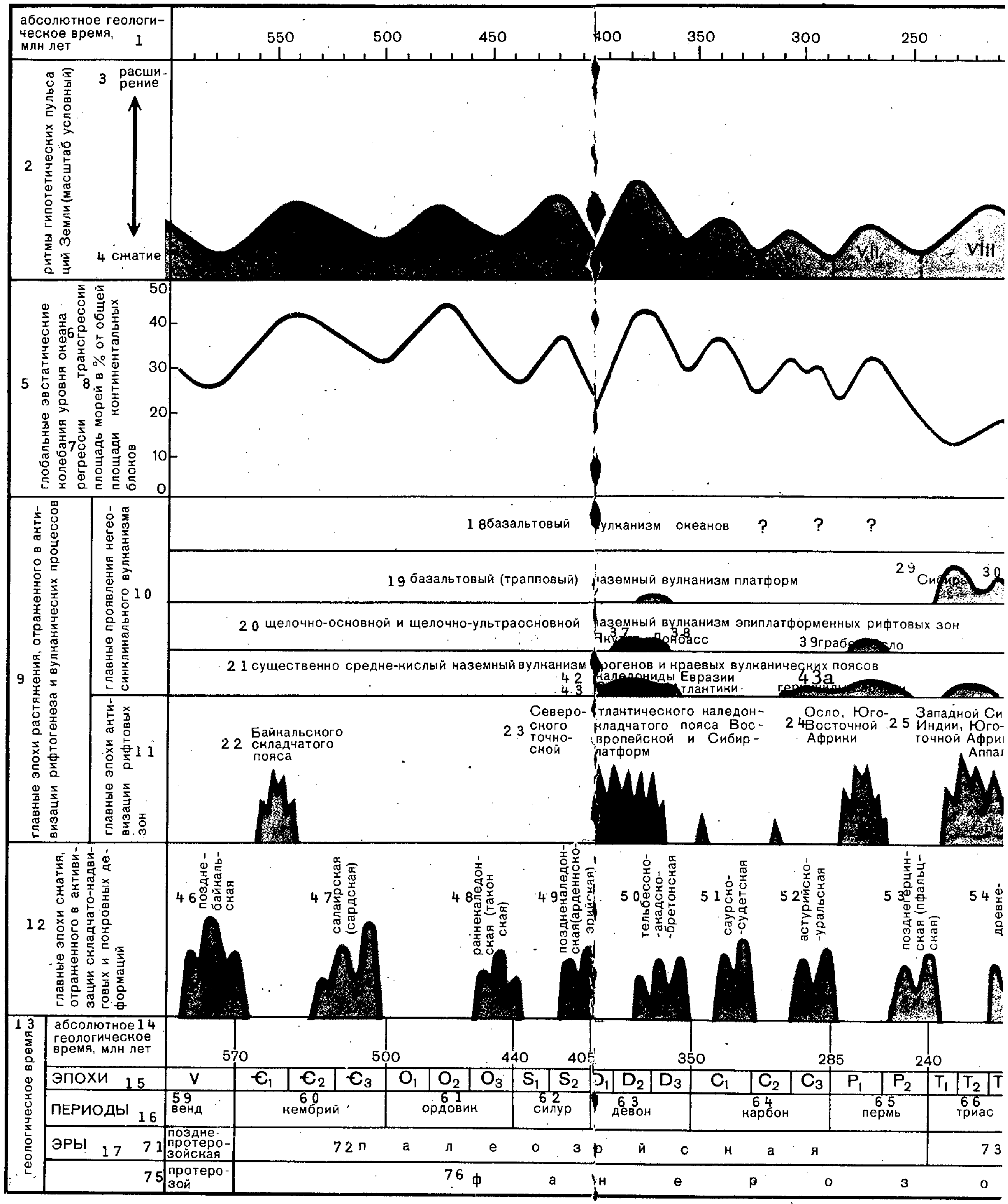
All these and many other important data have demanded a re-examination of views that have been put together concerning the structure of the earth's crust, its motion and evolution. Some of these data have been difficult to explain within the framework of "fixism," i. e. notions of invariability of relative locations on the scale of large structural elements of the earth's crust. This has led to the inception of mobilism in its various modifications. The most interesting attempt to account for and explain the new geological-geophysical data was made in a neomobilistic concept that showed up about ten years ago and is known as "global tectonics" or "lithospheric plate tectonics." One of the main merits of this intriguingly consistent and elegant idea that is now enjoying wide recognition in many nations of Europe

and America and is espoused by some geologists and geophysicists of the Soviet Union is its inherent global approach to analysis of tectonic motions and deformations that occur simultaneously in different regions of the earth.

Horizontal spreading and formation of the crust in some regions (such as the rift zones of the oceans) in accordance with the concept of plate tectonics must necessarily be compensated by corresponding squeezing and subduction of crustal material in other zones (geosynclinal belts). Of course in this connection it is postulated that the radius and volume of the earth have been invariable throughout geological history. The concept of plate tectonics deals most logically with the structure and origin of the basins of "young," "secondary" oceans (in particular the Atlantic); the explanation of the formation of these oceans was the primary purpose of creation of the theory, and the "rational kernel" of the concept lies precisely in the interpretation of the structure and development of these oceans.

At the same time, plate tectonics, laying claim to the role of a universal theory of tectogenesis, disagrees in its current form with many geological data, especially those relating to the structure and development of the continents. For instance one of the principal tenets of this hypothesis -- its assumption that thin lithospheric plates (of the order of 100 km thick) slide over the asthenospheric layer -- is difficult to square with the facts of prolonged inherited development of the largest structural regions of the continents, in particular the ancient platforms. For instance in the case of syneclises and anticlises (extensive depressions and relative elevations of the platform sheath) this duration reaches several hundred millions of years, and for large extensions of the crystalline base of platform-shields may even exceed 1-1.5 billion years. These facts are evidence of an unbroken and very prolonged connection between the crust of the ancient platforms (cratons) and the underlying mantle substrate to depths commensurate with the dimensions of the largest platform structures, i. e. down to a few hundred or even many hundreds of kilometers.

This conclusion agrees well with geophysical data obtained in the most recent years, well after the appearance of plate tectonics, showing that beneath the shields, right down to depths of 400-600 km there is no so-called layer of reduced velocities of seismic wave propagation (asthenosphere) or it shows up weakly, that the temperature in the upper mantle beneath the shields is several hundreds of degrees lower than at the same depths under the oceans, and the viscosity accordingly should be several orders of magnitude greater. Consequently the ancient platforms, and particularly the shields with their foundation right down to depths of 400 km, and perhaps to 600 km constitute a united whole, and the concept of thin lithospheric plates is not applicable to them. Figuratively speaking, the crust of the platform is securely "nailed" to the underlying upper mantle. If the shields do undergo horizontal displacement, it can take place only over much deeper zones of the mantle (or even over the surface of the core?), but not over the asthenospheric layer as depicted in the hypothesis of plate tectonics.



абсолютное геологическое время, млн лет 1
550
500
450
400
350
300
250
2 ритмы гипотетических пульсаций Земли (масштаб условный)
3 расширение
4 сжатие
VII
VIII
5 глобальные эвстатические колебания уровня океана
6 трансгрессии
7 регрессии
8 площадь морей в % от общей площади континентальных блоков
50
40
30
20
10
0
9 главные эпохи растяжения, отраженного в активизации рифтогенеза и вулканических процессов
10 главные проявления негеосинклинального вулканизма
18 базальтовый вулканизм океанов ? ? ?
19 базальтовый (трапповый) наземный вулканизм платформ
29 Сибирь
30
20 щелочно-основной и щелочно-ультраосновной наземный вулканизм эпиплатформенных рифтовых зон
37 Якутия
38 Донбасс
39 грабен Осло
21 существенно средне-кислый наземный вулканизм орогенов и краевых вулканических поясов
42 каледониды Евразии
43 Атлантики
43а герциниды Евразии
11 главные эпохи активизации рифтовых зон
22 Байкальского складчатого пояса
23 Северо-ского точно-ской
Атлантического каледонского складчатого пояса Восточно-Европейской и Сибирской платформ
24 Осло, Юго-Восточной Африки
25 Западной Сибири, Индии, Юго-Восточной Африки, Аппалачей
12 главные эпохи сжатия, отраженного в активизации складчато-надвиговых и покровных деформаций
46 позднебайкальская
47 салаирская (сардская)
48 раннекаледонская (таконская)
49 позднекаледонская (арденнская, эрийская)
50 тельбесско-акадско-бретонская
51 саурско-судетская
52 астурийско-уральская
53 позднегерцинская (пфальцская)
54 древне-
13 геологическое время
14 абсолютное геологическое время, млн лет
570
500
440
405
350
285
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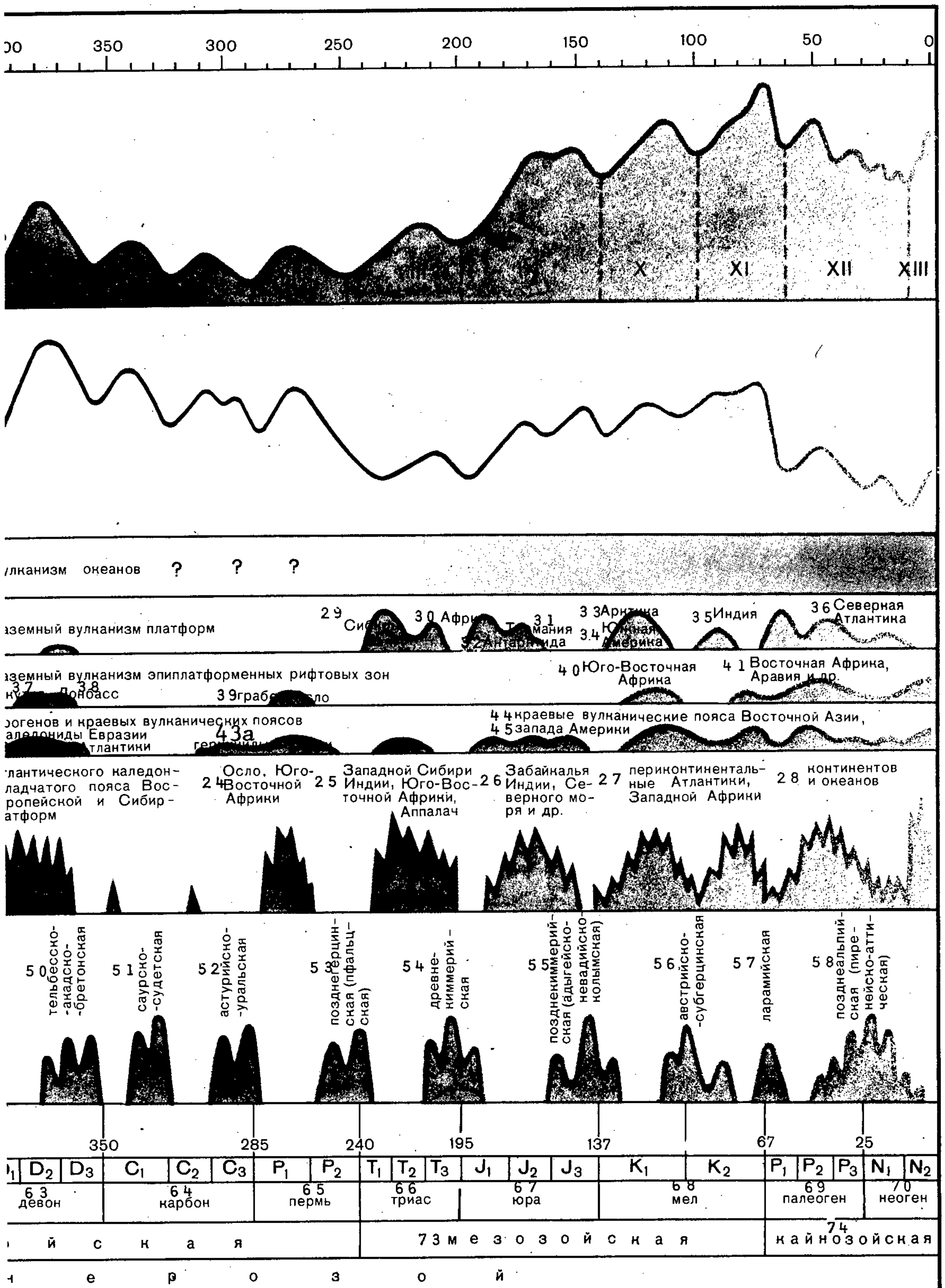
15 эпохи
V
$Є_1$ $Є_2$ $Є_3$ O_1 O_2 O_3 S_1 S_2 D_1 D_2 D_3 C_1 C_2 C_3 P_1 P_2 T_1 T_2 T
16 периоды
59 венд
60 кембрий
61 ордовик
62 силур
63 девон
64 карбон
65 пермь
66 триас
17 эры
71 позднепротерозойская
72 палеозойская
73
75 протерозой
76 фанерозо



350
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X
XI
XII
XIII
лканизм океанов ? ? ?
29 Си
30 Афр
31 мания
32 Антарктида
33 Арктика
34 Южная Америка
35 Индия
36 Северная Атлантика
земный вулканизм платформ
земный вулканизм эпиплатформенных рифтовых зон
37 38 Донбасс
39 грабен Осло
40 Юго-Восточная Африка
41 Восточная Африка, Аравия и др.
огенов и краевых вулканических поясов
аледониды Евразии
Атлантики
43а
44 краевые вулканические пояса Восточной Азии,
45 запада Америки
лантического каледон-
ладчатого пояса Вос-
ропейской и Сибир-
атформ
24 Осло, Юго-Восточной Африки
25 Западной Сибири Индии, Юго-Восточной Африки, Аппалач
26 Забайкалья Индии, Северного моря и др.
27 периконтинентальные Атлантики, Западной Африки
28 континентов и океанов
50 тельбесско-акадско-бретонская
51 саурско-судетская
52 астурийско-уральская
53 позднегерцинская (пфальцская)
54 древнекиммерийская
55 позднекиммерийская (адыгейско-невадийско-колымская)
56 австрийско-субгерцинская
57 ларамийская
58 позднеальпийская (пиренейско-аттическая)
350
285
240
195
137
67
25
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C1
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63 девон
64 карбон
65 пермь
66 триас
67 юра
68 мел
69 палеоген
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й с к а я
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CHART CAPTION: Correlation of global epochs of activation of tectonic deformations, volcanism, eustatic cycles and assumed pulsations of the earth in the Phanerozoic

KEY: 1--Absolute geological time, millions of years
2--Rhythms of hypothetical pulsations of the earth (arbitrary time scale)
3--expansion
4--compression
5--Global eustatic oscillations of ocean level
6--transgression
7--regression
8--area of seas in % of total area of continental blocks
9--Principal epochs of expansion as reflected in activation of riftogenesis and volcanic processes
10--Principal manifestations of non-geosynclinal volcanism
11--Principal epochs of activation of rift zones
12--Principal epochs of compression as reflected in the activation of fold-upthrusting and sheath deformations
13--Geological time
14--Absolute geological time, millions of years
15--Epochs
16--Periods
17--Eras
18--Basaltic volcanism of oceans
19--Basaltic (traprock) surface volcanism of platforms
20--Alkali-basic surface volcanism of epiplatform rift zones
21--Appreciably neutral-acid surface volcanism of orogenies and fringe volcanic belts
22--Baykal folded belt
23--North Atlantic Caledonian folded belt of the East European and Siberian platforms
24--Oslo, Southeast Africa
25--West Siberia, India, Southeast Africa, Appalachia
26--Trans-Baykal, India, North Sea, etc.
27--Pericontinental rifts of the Atlantic, West Africa
28--Rift zones of continents and oceans
29--Siberia
30--Africa
31--Tasmania
32--Antarctica
33--The Arctic
34--South America
35--India
36--The North Atlantic
37--Yakutia
38--Donbass
39--Oslo Graben

[KEY CONTINUED ON FOLLOWING PAGE]

CONTINUATION OF KEY TO CHART]

40--Southeast Africa
41--East Africa, Arabia, etc.
42--Caledonian orogenies of Eurasia
43--of the North Atlantic
43a--Hercynian orogenies of Eurasia
44--Fringe volcanic belts of Eastern Asia
45--of Western America
46--Late Baikalian
47--Salairian (Sardian)
48--Early Caledonian (Taconic)
49--Late Caledonian (Ardennic-Erian)
50--Telbessian-Acadian-Bretonian
51--Saurian-Sudeten
52--Asturian-Uralian
53--Late Hercynian (Pfalzian)
54--Old Cimmerian
55--Late Cimmerian (Aldygeyan-Nevadan-Kolyman)
56--Austrian-Subhercynian
57--Laramide
58--Late Alpian (Pyrenean-Attic)
59--Wendian
60--Cambrian
61--Ordovician
62--Silurian
63--Devonian
64--Carboniferous
65--Permian
66--Triassic
67--Jurassic
68--Cretaceous
69--Paleogenic
70--Neogenic
71--Late Proterozoic
72--Paleozoic
73--Mesozoic
74--Cenozoic
75--Proterozoic
76--Phanerozoic

In its present form the concept of plate tectonics does not give due consideration to the irreversible directed development of the earth in the course of its history, the unrepeatable peculiarities of individual geological epochs. There is considerable doubt concerning the valid basis for mechanical extrapolation by some proponents of this concept as applied to the model of motion of lithospheric plates worked out for the Cretaceous-Cenozoic to more remote periods in the history of the earth, right back to the Paleozoic, or even the Precambrian (more than 570 million years ago).

The concept of plate tectonics does not as yet explain the nonuniformity of the process of tectonic development in time, the existence of phases and epochs of activation of tectonic motions (orogenic phases or folding phases) that are of planet-wide significance in a number of instances[2], or the global variations (so-called eustatic oscillations) of the ocean level that cause transgressions and regressions. This concept does not reveal the nature of more prolonged geotectonic cycles or the reasons for the most extensive irreversible changes in the nature of the structure and development of the earth in the course of its geological history.

Finally, it should be pointed out that although the concept of plate tectonics in principle presupposes reciprocal balance between horizontal motions and deformations of the crust on a global scale, in the practice of developing kinematic "geohistorical" models that reconstruct the evolution of individual regions, as for example folded areas, their authors are sometimes very arbitrary in "moving" the plates bordering these regions in different directions without being concerned about the unavoidable results in other regions

of the earth. The number of such disagreeing special kinematic models is snowballing, and of course their multiplicity and ambiguity are doing nothing to reinforce confidence either in the models themselves or in the concept of plate tectonics as a whole.

On the basis of these facts, we feel that although the hypothesis of plate tectonics does contain some progressive and valuable elements, it cannot yet be considered a satisfactory overall geotectonic theory, and ways should be sought for creating a more complete concept that satisfies the entire aggregate of diverse geological and geophysical data that at first glance seem so inconsistent.

PERIODICITY OF TECTONIC MOTIONS AND EUSTATIC OSCILLATIONS IN THE PHANEROZOIC

One of the most important patterns in the development of the earth during the Phanerozoic has been the nonuniformity of manifestation of tectonic deformations in time. This was first clearly formulated by G. Stille as the well known canon of orogenic phases, or phases of folding, that have general, planet-wide significance. Subsequently, the ideas of relative short duration and the global nature of manifestation of these phases and their universal simultaneity have been questioned by N. S. Shatskiy, Dzh. Gilluli and other researchers; however, currently the nonuniformity of tectonic deformations in time and the periodicity of this process, including on a planet-wide scale, is becoming more and more evident.

In 1969-1973, Ural tectonics expert A. A. Pronin wrote several monographs generalizing the enormous material in the literature on the chronology of tectonic motions on all continents during the Phanerozoic. A statistical analysis of this material undertaken by N. Ya. Kunin and N. M. Sardonnikov led to the conclusion that during the Phanerozoic (to be more precise, since the end of the Wendian) there have been 13 planet-wide "cycles" of tectonic activity with average duration of about 40-45 million years. Each of these "cycles" consists of two epochs of nearly equal length, one being characterized by intensification of fold-forming motions that show up in profile cross sections as breaks and angular unconformities, while the other epoch is characterized by an abatement or even total lack of deformations of this kind. The following tectonically active epochs can be clearly distinguished in the structure of geosynclinal regions of the geological past: Late Baikalian (the very end of the Precambrian), Salairian (second half of the Cambrian), Early Caledonian (end of the Ordovician), Late Caledonian (end of the Silurian), Acadian-Bretonian (second half of the Devonian), Sudeten (middle of the Carboniferous), Uralian (end of the Carboniferous), Late Hercynian (second half of the Permian), Early Cimmerian (end of the Triassic), late Cimmerian (second half of the Jurassic), Austrian (middle of the Cretaceous), Laramide (end of Cretaceous to beginning of Paleogene) and Alpian (second half of Paleogene to Miocene).

In recent years it has been established by some Soviet (V. G. Kaz'min) and non-Soviet (A. Pilger, A. Resper and others) researchers that tectonic

deformations in rift zones (where horizontal spreading predominates) and their corresponding magmatic processes also take place nonuniformly in time. Epochs of intense widening and deepening of rifts alternate with epochs of abatement or cessation of motions of this kind. Such nonuniformity has been reliably established for the Rhine, Kenya, Red Sea and many other modern and ancient rift zones. A comparative study of many modern and ancient rift zones gives evidence in favor of both periodicity in development of the rift process in separate rift zones and belts, and the existence of global epochs and phases of riftogenesis of the same duration as the epochs and phases of fold-forming motions, i. e. deformations of compression in geosynclines. But if this is so, questions naturally arise about whether the planet-wide periodicity of fold-forming and sheath deformations in geosynclines is related to the periodicity of manifestations of riftogenesis, and how motions in these zones are correlated in time.

We can now give a definite affirmative answer to the first question. As to the second question, if invariability of the radius and volume of the earth are postulated, one would obviously have to assume simultaneity of compression in geosynclinal regions and expansion in rift zones, i. e. mutual compensation of the effects of these deformations on the global scale. Indeed, this is the way that the problem is handled from the standpoint of plate tectonics, for instance by the West German geologist W. Schwann. However, it should be noted from the outset that while the rift process took on significance comparable with the geosynclinal process in the mesozoic and especially in the Cenozoic, the role of riftogenesis in the Paleozoic, at least on the continents (and so far we know nothing about the Paleozoic oceans!) was still quite insignificant on the whole, and we have no basis for assuming compensation of the deformations of compression in the Paleozoic geosynclines by expansion in rift zones.

A detailed study of the chronology of motions in modern and ancient rift zones of the earth undertaken by the author shows that epochs of intensification of riftogenesis actually do not coincide with epochs of augmentation of the formation of folds and tectonic sheaths, i. e. the deformations of compression in geosynclinal regions and some adjacent zones of platforms, but rather alternate with them in time. This pattern is particularly obvious in the Late Cenozoic. For instance the Miocene Epoch was the time of most intense deformations of tangential compression in Alpian geosynclinal regions, and at the same time was an epoch of abatement of processes of riftogenesis, while on the other hand in the Pliocene-Anthropogene the deformations of spreading in rift zones of the continents and oceans are sharply activated, and folding-sheathing deformations are abruptly damped out in most Alpian structures. On the whole, the Phanerozoic and especially the Mesocenozoic history of the earth is comprised of alternating epochs that are distinguished from one another not so much by the intensity of tectonic motions and deformations as by the nature and partly by the distribution of these deformations over the earth's surface.

It would be erroneous to assume that deformations of compression showed up only in geosynclinal regions, while deformations of expansion were observed

solely in rift zones. It is well known that during the concluding orogenic stage of development of a geosynclinal region (when mountain structures are being formed within its limits) fold-forming motions may cover several sections of the adjoining platforms, both those in direct proximity to the region and those removed from it, sometimes by hundreds of kilometres. Folding-thrusting deformations, and sometimes sheath deformations as well that are typical of geosynclinal regions, are also fairly widely spread in many ancient continental rift zones, beginning with the Late Proterozoic and ending with the Mesozoic, and in isolated instances even with the Paleogene. They are lacking (so far) only in recent rift zones. In these zones, deformations of compression follow phases of active riftogenesis (sometimes alternating with them), and correspond in time with epochs of folding formation in geosynclinal and orogenic regions.

The expansion of intra-oceanic rift zones has also taken place nonuniformly with time; some researchers assume with good basis that epochs of compression deformations and regional metamorphosis have taken place in the development of zones of this kind (in particular the Mid-Atlantic Ridge) that most likely correspond to the Laramide (according to A. V. Peyve[3]) or Pyrenean (according to V. M. Lavrov) phase.

On the other hand, there is no doubt that there have been epochs of more or less considerable spreading as well in the development of all geosynclinal belts. Such epochs or stages of development of geosynclines, which in the nature of the deformations are like the development of rift zones, have been called "riftogenic" by some researchers; it would be better to call them "rift-like." Expansion that had taken place on the early stages of the geosynclinal cycle led to thinning of the continental crust, or even to total destruction and bursting, and to the formation of a new thin crust of oceanic type in the resultant "notches." These processes showed up especially strongly in the ophiolitic zones of the geosynclinal belts. Subsequently in the compression phases (but as a rule still long before completion of the "cycle" of development of the geosynclinal belt) it is these zones that were subjected earlier than others to the strongest compression and squeezing with formation of what is called a serpentinite melange[4] of tectonic sheaths.

Some zones of geosynclinal belts may periodically undergo sharp expansion even on later stages of the geosynclinal cycle, particularly not long before the end of the phase of geosynclinal subduction, and also at the end of the subsequent orogenic stage (the mountain-forming phase), as occurred for instance in the Pliocene-Anthropogene, i. e. over the last 5-10 million years in the Mediterranean Sea Belt.

Thus the history of the earth during the Phanerozoic is comprised of consecutively occurring epochs of augmentation of compression and expansion. In the Cenozoic and Mesozoic the principal regions of deformations of both types included both geosynclinal and rift belts and zones, although on the whole compression showed up much more strongly in geosynclinal belts that were chiefly zones of deep subduction and "suction" of crustal material, while

expansion was realized mainly in regions of riftogenesis, where deep mantle material filling the "gaps" formed in the crust was elevated, and this "plug" impeded further strong compression of rift zones. The scale of horizontal spreading was relatively small (kilometres) in continental rift zones, more appreciable (many tens of kilometres) in intercontinental zones (like the Red Sea Rift), and greatest in the rift belts of the oceans, where as a result of summation of the effect of repeated phases of expansion during the Mesozoic and Cenozoic it might have reached several hundred, and perhaps a few thousand (?) kilometres. As for the platforms, at least on isolated sections they also have undergone periodic deformations of expansion and compression, but much smaller than in tectonically active zones.

The role of geosynclinal processes and the extent of geosynclinal belts in the course of the Late Proterozoic and Phanerozoic has successively declined, while the role of riftogenesis and the extent of rift zones and belts has increased with time. Thus the approximate, perhaps illusory balance of these processes that we observe in the Cenozoic could not have taken place in the past -- in the Paleozoic, and even moreso in the Late Proterozoic. One might think that the geosynclinal regions that once belted the earth in a comparatively dense and branching network comprised the principal and almost the only type of moving zones of the earth's crust in the Late Proterozoic and the Paleozoic, and that it was within the limits of these regions that both compressive and expansive deformations alternately occurred. But with the gradual fading of individual geosynclinal belts or parts of them and the corresponding expansion of the overall area of the bordering "stable" regions, independent zones of spreading -- rift zones -- more and more frequently arose within the limits of the "stable" regions. As a rule, they used the tectonically "weakened" zones of the platform substrate, and thus inherited the configuration of ancient linearly folded and fault structures. Consequently the zones of predominating horizontal expansion and contraction that originally belonged to ancient geosynclines have been divided in the course of geological history between rift and geosynclinal regions respectively[5].

Apparently associated with alternation of epochs of predominant compression and expansion in the Phanerozoic are eustatic oscillations of the level of the World Ocean showing up as world-wide transgressions and regressions. Although the behavior of the encroachments and withdrawals of the sea on individual platforms and continents undoubtedly reflects peculiarities of development of these regions, nonetheless a careful analysis of actual data using the results of computations of areas of all continents with respect to paleogeographic maps leads many researchers to recognize the reality of existence of major global eustatic cycles. It is striking that the number of these major cycles as established by independent data is equal to the number of cycles of tectonic activity, the world-wide regressions coinciding with epochs of intensification of compressive deformations, while the world-wide transgressions correspond to the alternate relatively "quiet" epochs of the Paleozoic, or to the epochs of augmentation of expansive deformations in the Devonian and Mesocenozoic. In all probability the relation between regressions and epochs of compression is due to an increase in the amplitude of

major irregularities of the earth's surface, and in particular to an increase in the depth and capacity of ocean basins in epochs of this kind. The alternate epochs of expansion and transgressions are characterized by smoothing of these irregularities, and in the Late Mesozoic and the Cenozoic possibly also by an increase in growth of intra-oceanic rift ridges that reduces the capacity of the ocean basins.

PATTERNS OF DEVELOPMENT OF VOLCANISM IN THE PHANEROZOIC

During the Paleozoic, geosynclinal volcanism (to a considerable extent under water) reigned supreme in regions of the earth that are accessible to study. Only during the Devonian and Permian was there some increase in the part played by orogenic surface volcanism, and in the Devonian there were also slight basaltic and alkaline eruptions on some ancient platforms.

In the Mesozoic and Cenozoic the significance of geosynclinal volcanism in connection with gradual disappearance of the geosynclinal belts rapidly declines; but at the same time there is an abrupt rise in the role played by extra-geosynclinal types of continental volcanism: traprock formations of platforms (volume of products -- 10-15 million km^3), neutral-acid formations of fringe volcanic belts (at least 10 million km^3) and formations of alkali-mafic and alkali-ultramafic rocks in regions of tectonic activation (including the rift zones of platforms). The total volume of products of these types of Mesocenozoic continental volcanism (nearly absent in the Paleozoic), according to the author's calculations reaches 25-30 million km^3. Thanks to the powerful development of extra-geosynclinal volcanism, the average intensity of the volcanic process within the limits of the present continents does not decrease on the whole throughout the Mesozoic and Cenozoic despite the gradual disappearance of geosynclinal belts[6], but a sharp redistribution takes place in volcanic activity on the earth.

All the basaltic volcanism of oceans that we now know of belongs to the Mesozoic and Cenozoic, and the overall volume of its products can be conditionally estimated at a minimum of 300-400 million km^3. Thus in its scale the volcanism of oceans in the Mesozoic and Cenozoic is more than 10-15 times the extra-geosynclinal volcanism of the continents. The powerful development of the latter during the Mesozoic and Cenozoic is associated with abrupt activation of processes of riftogenesis on a world-wide scale. There is an intimate spatial relation between the volcanic fields of the oceans and the regions of Mesocenozoic extra-geosynclinal volcanism of the continents. Therefore we have a sound basis for assuming that volcanic activity within the limits of the present ocean floor (probably also including the ancient Pacific Ocean bed) also increased appreciably during the Mesozoic and Cenozoic analogously with the extra-geosynclinal volcanism of the continents.

If this assumption is valid, then it should be acknowledged that during the Mesozoic and Cenozoic there was not only a redistribution of zones of intense release of thermal energy among the major types of tectonic regions, but also a considerable increase in the thermal parameters of the upper mantle and the

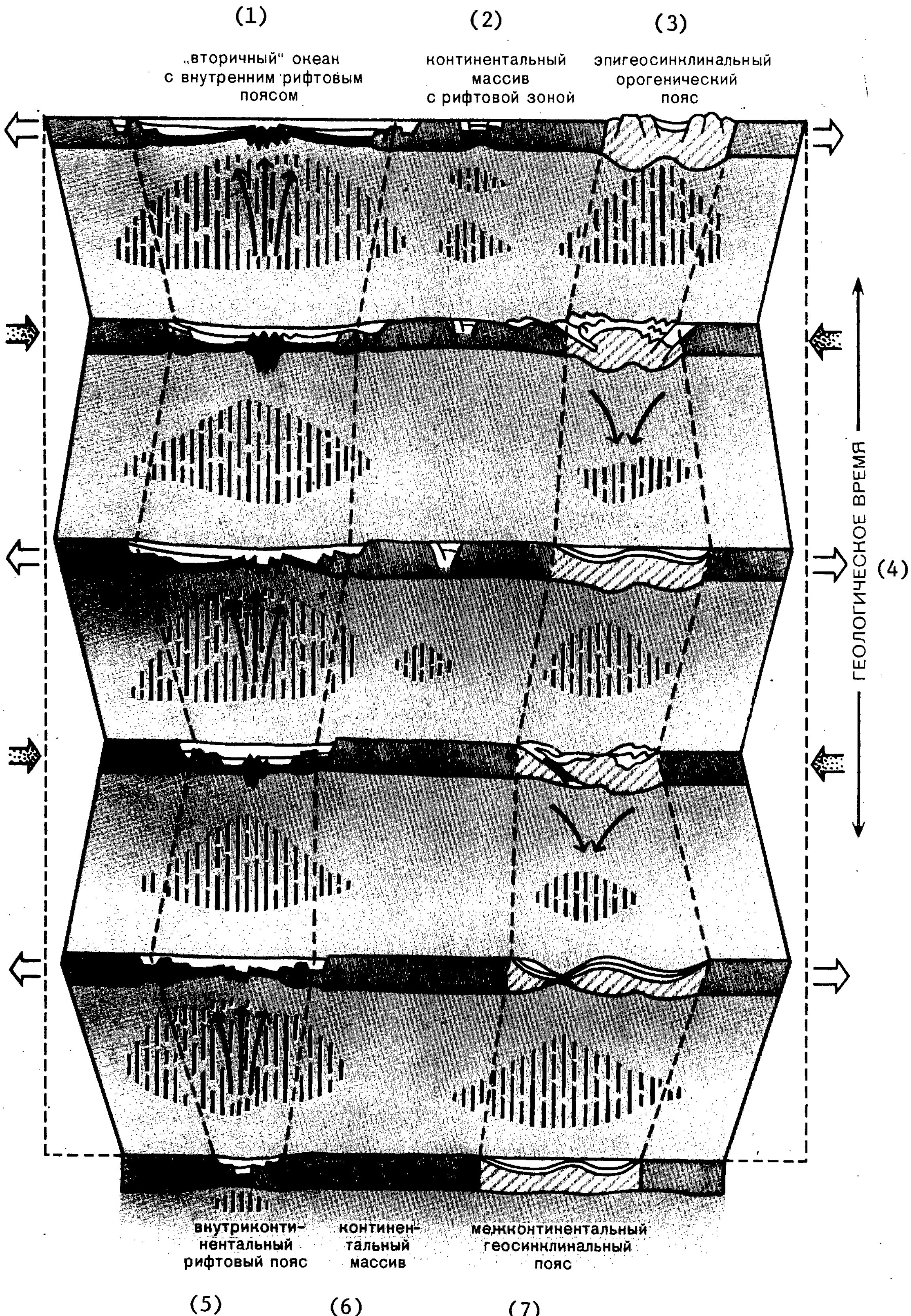
crust over the entire earth. Judging from the relative prevalence of volcanic formations of different ages within the limits of the continents and ocean bottom, there was apparently an increase in the intensity of heat release on the surface of the planet throughout the entire Mesozoic, reaching a maximum during the Cretaceous, and once again subsiding in the Cenozoic. Traprock volcanism nearly ceases in the Oligocene-Miocene, volcanic fringe belts deteriorate, and zones of basaltic volcanism in the ocean abruptly decrease in width. The time of formation of "secondary" oceanic basins falls chiefly into the Jurassic-Paleogene, i. e. into the epoch of highest volcanic activity over the greater part of the earth's surface. In all probability the formation and renewal of the ocean basins on the one hand and the abrupt activation of riftogenesis and volcanism on the other hand are different manifestations of a single deep-level process covering our planet in the Mesozoic-Cenozoic.

According to today's models of the thermal history of an initially cold earth (Ye. A. Lyubimova, B. Yu. Levin, S. V. Mayeva and others) the internal temperature at all depth levels except for the top 500 km has gradually increased throughout the history of the earth, and in this connection the temperatures in the upper mantle during the Phanerozoic have come close to the melting points at the corresponding depths, or might even have slightly exceeded them. According to calculations by A. N. Tikhonov et al.[7] the process of heating of the depths and melting of the upper mantle as a result of deep-level heat flow should undulate in time with a period of the order of 140-170 million years, the last "wave" of partial or total melting having reached the upper parts of the mantle between 200 and 50 million years ago, i. e. in the Jurassic-Paleogene, which agrees well with data of geology on the enormous scale of volcanism in the oceans and on the continents at just this time.

Against a background of overall global activation in the Mesozoic-Cenozoic as compared with the Paleozoic, one can also distinguish a number of epochs of relative intensification of volcanism, separated by epochs of abatement. The volcanically active epochs in the main coincide with epochs of riftogenesis (which is completely natural since the volcanic process takes place in an environment of some horizontal spreading), while epochs of abatement or cessation of volcanism coincide with epochs of intensification of deformations of compression.

PERIODIC EXPANSION AND CONTRACTION OF THE EARTH

Repeated alternation of epochs of augmentation of deformations of compression and expansion in the earth's crust, and of world-wide transgressions and regressions, and also major trends in the development of geosynclinal and rift belts, ocean basins and volcanism during the Phanerozoic are difficult to explain without assuming phenomena of overall expansion and contraction of the earth that must have been repeated many times throughout its history. We are speaking in the first place of pulsations of the body of the planet with periodicity averaging about 40-50 million years (during the Phanerozoic), and secondly of a much more prolonged process of expansion of the earth that



[Caption, legend and key for this diagram are on the following page]

CAPTION FOR FIGURE ON PRECEDING PAGE: Diagram of evolution of the structure of the earth's crust during the Mesozoic and Cenozoic in the process of overall expansion of the earth complicated by pulsations. The vertical scale is strongly exaggerated as compared with the horizontal. It is arbitrarily assumed that in each epoch of global expansion 3/4 of the total horizontal transverse spreading in the depicted section of the earth takes place in a rift belt, while 1/4 takes place in an intercontinental geosynclinal belt [of the Mediterranean Sea type]. In each subsequent phase of global compression the total horizontal contraction of the surface amounts to 75% of the total expansion in the preceding phase, 2/3 of the horizontal compression falling to a geosynclinal belt in which folding-thrusting structures are formed along with tectonic sheaths, while 1/3 of the compression falls to a rift belt [in reality, the percentage of the latter may be much less of the total contraction]. In the course of repeated intermittent expansion the intracontinental rift belt is transformed first to an intercontinental rift belt, and then to a secondary (young) ocean basin with an intra-oceanic rift belt in the middle part. As a result of a number of pulsations of the earth, the geosynclinal belt gradually contracts. The consolidated continental masses divided by rift belts (secondary oceans) gradually move away from one another, while the continental masses divided by geosynclinal belts get somewhat closer together; these relative horizontal displacements in combination cover the crust and the upper mantle of the continental masses to a depth of at least 600 km.

Crust of continental type of consolidated regions (platforms) and continental rift zones

Crust of continental and intermediate types of geosynclinal belts

Crust of oceanic type

Sedimentary layer (including deformed)

Upper mantle

Asthenosphere

Ascending direction of motion of mantle material

Descending direction of motion of mantle material

Horizontal spreading of crust and upper mantle in epochs of expansion of the earth

Horizontal contraction in epochs of compression of the earth

KEY:
1--Secondary ocean with internal rift belt
2--Continental mass with rift zone
3--Epigeosynclinal orogenic belt
4--Geological time
5--Intracontinental rift belt
6--Continental mass
7--Intercontinental geosynclinal belt

occurred over the entire Mesozoic and Paleogene, and that ceased or was even replaced by some contraction in the Oligocene-Miocene; it is possible that these prolonged changes in the volume of the planet also reflect the existence of a periodic process, but with greater duration of oscillations. Finally, it can be assumed that shorter periodic oscillations of the volume of the earth have also existed with extrema that are reflected in particular in the presence of individual phases of folding formation and riftogenesis.

The idea of pulsations of the earth and the concomitant periodicity of many tectonic, magmatic, paleogeographic and other processes has been repeatedly expressed in the geological literature throughout our century. It was first clearly formulated in 1933 by the U. S. Geologist W. Bucher in the book "Deformations of the Earth's Crust" and was developed in 1940 by V. A. Obruchev and M. A. Usov. Recently this hypothesis has once more attracted attention. P. N. Kropotkin has analyzed the part played by a number of cosmic and physical factors that may cause periodic changes in the radius of the earth of different durations and amplitudes, and has demonstrated the possibility of these oscillations. A reduction in the volume of the earth should be accompanied by an increase in the rate of rotation and enhanced polar flattening, and vice versa -- an increase in volume should be accompanied by slowing of rotation and a reduction in polar flattening, which should lead to considerable redistribution of masses in the water envelope, crust and mantle of the earth. The tectonic consequences of changes in the volume, rate of rotation and shape of the earth have been examined by G. N. Katterfel'd.

Acknowledging the periodicity of epochs of folding formation, transgressions and regressions, many researchers have treated the history of the earth as an alternation of tectonically active and relatively quiet epochs. In our estimation, the history of the earth should be seen as an alternation of epochs of predominance of global compression and global expansion. The former are characterized chiefly by strong contraction of the width of geosynclinal belts; in their upper crustal parts, folds, upthrusts and tectonic sheaths are formed, while in the deep parts of the crust and the upper mantle there are deep-level overthrusts, underthrusts of individual blocks of the lithosphere or suctioning of the edges of adjacent blocks. To a much smaller degree the contraction of the volume of the earth shows up in horizontal compression of tectonically "stable" regions as well as rift zones, or simply in the cessation or abatement of expansion in the latter. The general warping of the earth's crust in these epochs leads to planet-wide regressions. Volcanism in these epochs is either lacking or shows up extremely slightly and locally.

The increase in the surface of the earth as it expands shows up mainly in rift zones and belts (principally the rift zones of oceans). The overall effect of this intermittent expansion during the Mesozoic-Cenozoic in some ocean basins, and above all in the Atlantic Ocean, may have reached many hundred, or even more than a thousand (?) kilometres. However, the expansion of the surface of the earth in oceanic rift belts and the formation of an

oceanic crust there due to the elevation of deep-level mantle material has been partly compensated by its contraction in a number of tectonic zones of the earth (mainly in geosynclinal belts) in epochs of predominant compression.

Thus the masses of the continental crust during the course of the Mesocenozoic might have changed their relative positions (diverging and converging) without becoming detached from the upper mantle in the process, at least to a depth of 600 km. Horizontal spreading in epochs of expansion of the earth in the Mesocenozoic also took place in geosynclinal belts, mainly on relatively early (especially in ophiolitic zones) and late stages of their development. In the Premesozoic Era, when riftogenesis was still unimportant as an independent tectonic process, the main zones of expansion were the geosynclinal belts themsleves. Most manifestations of volcanism were confined to epochs and phases of expansion of the earth: in the Paleozoic -- chiefly in geosynclinal belts, and in the Mesozoic and Cenozoic, when most of these belts had disappeared -- chiefly in the oceans as well as in all other tectonic zones of the earth. The smoothing of major irregularities of the earth's surface in epochs of its expansion, and at the end of the Mesozoic and Cenozoic also the augmentation of growth of ocean rift ridges in these epochs led to "world-wide" transgressions.

It can be assumed that the very first separation of linear moving zones that formed a very dense network in the crust and mantle of the earth on the one hand, and relatively stable masses lying in the cells of this network on the other hand sometime in the Archean (3.5-2.6 billion years ago) and the early Proterozoic (2.6-1.7 billion years ago), was associated with pulsation behavior of the planet, specifically with disruption of the "primary" crust of the earth during the earliest phases of its expansion. It should be emphasized that in connection with the heterogeneity of the structure of the crust of the earth the real pattern of motions on the face of the earth was always very complicated, and therefore in epochs of general expansion, some zones may have undergone compression, while in epochs of predominant compression, some zones may have been subjected to spreading, shearing and so on.

The causes of the assumed oscillations of the volume of the earth as yet remain unclear. It is possible that they are associated with pulsating flow of the thermal energy coming from the depths of the earth, from the boundary between the core and the mantle up to the surface.

Against a background of comparatively short-term pulsations of the earth in the Phanerozoic, there have apparently been more prolonged directional changes in its volume. It is most probable to assume general expansion of the earth in the course of the Mesozoic and Paleogene when spreading, subsidence, and basaltic effusions on an enormous scale in space and time resulted in formation of the Atlantic, Indian and Arctic ocean basins much as we seen them today, and in "renewal" of the Pacific Ocean bed. This time was an epoch of very powerful extra-geosynclinal volcanism on the continents, volcanism still more powerful in the oceans, and also an epoch of abrupt activation of riftogenesis both in the modern oceans and on the continents.

All these phenomena in the aggregate may indicate considerable heating of the upper mantle of the earth in the Mesozoic and Paleogene, development of zones of melting in the upper reaches of the mantle beneath extensive areas of the earth's crust accompanied by an increase in volume, a reduction in viscosity of the asthenosphere and an increase in the capacity of lithospheric blocks for horizontal displacement. Therefore if motions of lithospheric plates over the asthenosphere like those described by the hypothesis of plate tectonics did indeed take place at some time, then the most favorable time for them was precisely in the second half of the Mesozoic and Paleogene.

From the geological standpoint, the idea of some general expansion of the earth in the Mesocenozoic, like the idea of periodic pulsations of the earth, is very likely, although the scale of the expansion remains insufficiently clear. This idea, which was expressed independently as far back as in the thirties by the geophysicist O. Hilgenberg, astronomer D. Holm and Soviet geologists M. M. Tetyayev and V. M. Bukanovskiy, is lately getting more and more support from eminent scientists both in our nation and elsewhere[8] (including some proponents of plate tectonics).

We feel that the concepts expressed above agree with the most important empirical principles of the structure and development of the earth's crust as a whole and of its major tectonic zones -- continents and oceans, geosynclinal and rift belts -- that are the basis both for modern fixist and for mobilist concepts, and at the same time remove certain difficulties and contradictions that these concepts have run up against. These concepts provide a natural explanation of global periodicity in manifestations of compressive deformations in geosynclines, riftogenesis, volcanism and large-scale oscillations in the level of the World Ocean. The proposed concept satisfactorily "accommodates" such important landmarks of the geosynclinal process as "uncovering" of ophiolitic zones with crust of oceanic type and their subsequent "covering," strong contraction of the width of geosynclinal belts and intense fold-sheath deformations at the end of the geosynclinal "cycle" and so on. The concept covers the formation of numerous rift zones during the Mesocenozoic, as well as the formation of young ocean basins as zones of the greatest horizontal spreading and most intense heating, elevation of deep-level material and large-scale basaltic effusions, accompanied by deep reworking and subsidence of the crust in the peripheral zones of these basins. At the same time, the concept does not tear blocks of continental crust from their mantle substrate, and agrees with the ideas of prlonged hereditary development of platform structures.

FOOTNOTES

1. Phanerozoic -- the last 570 million years of the earth's history.

2. Although some proponents of plate tectonics do acknowledge the presence of phases of this kind.

3. A. V. Peyve, "Tectonics of the Mid-Atlantic Ridge," GEOTEKTONIKA, No 5, 1975.

4. A serpentinite melange is a kind of tectonic breccia made up of fragments of ultramafic (chiefly serpentinites) and mafic (gabbros, diabases, spilites) igneous rocks, cherts (radiolarites) and so on.

5. Ye. Ye. Milanovskiy, "Riftogenesis and the Geosynclinal Process," VESTNIK MOSKOVSKOGO GOSUDARSTVENNOGO UNIVERSITETA, SERIYA GEOLOGICHESKAYA, No 4, 1975.

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PHYSICS

SOVIET LASER SPECTROSCOPY RESEARCH REVIEWED

Moscow IZVESTIYA in Russian 19 Aug 78 p 3 LD

[Article by Prof V. Letokhov, Lenin Prize winner: "Laser Counts Atoms"]

[Text] "...The history of the study of light and its nature and essence is far from complete. There is no doubt that new discoveries await science in this field, that we will move closer to the truth, and that our hardware will become enriched with new facilities." These words, written in 1950 by outstanding Soviet optical physicist Academician S. Vavilov, proved prophetic. A decade later quantum generators of coherent light were developed and a new avenue in science and technology--quantum electronics--emerged.

Coherent light consists of electromagnetic oscillations which are extremely regular in terms of time and space. In a quantum generator--a laser--a tremendous number of atoms and molecules synchronously emit particles of light which form a beam with a strictly determined wavelength, direction of emission, intensity, and so forth. A laser beam can be made to take the form of a pencil beam or focused on a point only microns across.

The development of quantum generators led to the discovery of a completely new area of optics--nonlinear optics--created through the works of the scientific school of academician R. V. Khokhlov. Nonlinear optical methods have extended to an exceptional degree our opportunities for controlling the parameters of beams of light. The wavelength of emissions can be modified over a very broad range in nonlinear crystals. For example, very weak invisible infrared radiation can be made visible. The unique properties of laser light have made it possible to develop essentially new methods for studying matter. It is these I would like to describe in this article.

Optical spectroscopy occupies an important place among the traditional methods for studying the structure and composition of matter. It is based on the ability of prisms and certain other optical instruments to split a beam of white light into separate colors--in other words to "separate out"

electromagnetic oscillations with different wavelengths. Atoms or molecules of every substance are characterized by individual spectral lines corresponding to the wavelengths of the electromagnetic oscillations specific to them.

A coherent laser beam with a modifiable wavelength enables scientists to study matter with a degree of resolution and sensitivity millions of times greater than the most effective traditional methods. The new method is based on the selective resonance effect of laser light on atoms and molecules.

Imagine a physical map covered with symbols of the most diverse shapes and sizes signifying deposits of certain given useful minerals. There are many symbols. In places they overlap, and it is practically impossible to single out all the symbols of the same kind and to convert them. But say we flick a switch and lights light up in the squares corresponding to coal deposits. Flick another switch and other lights corresponding to, say, oil deposits light up. Flick yet another switch and a single tiny light lights up in one corner of the map: a region where a deposit of some very rare mineral has been discovered....

In precisely the same way, nonlinear laser spectroscopy methods enable us to "spotlight" among the dense network of spectral lines the ones which correspond to the atoms of the substance we need. The role of the "switches" here is played by the different wavelengths of laser beams, while the role of the "lights" is played by the induced pulses from atoms excited by an electromagnetic field. At the USSR Academy of Sciences Institute of Spectroscopy a comparatively simple laser device makes it possible to reliably detect individual atoms of sodium, ytterbium, and other elements.

The new method is of tremendous interest to specialists in nuclear physics because with its aid it is possible to detect a new element or isotope or an unusual nucleus during the short space of time it is actually at the accelerator target. Prospects are emerging for developing qualitatively new analytical instruments for the most diverse national economic needs, particularly for geology.

We are currently learning to apply the laser spectroscopy method to the investigation of molecules. The first successful experiments conducted recently proved that the solution of such problems is possible. We are progressing toward elaborating a method for detecting minute organic impurities and developing instruments comparable with human and animal olfactory organs in terms of sensitivity. In the view of academician P. Kapitsa, "emulating the canine sense of smell" is a real and important problem for physics in the future.

Laser radiation has substantially broadened the sphere of application of the spectroscopy method and has moved it beyond the bounds of traditional problems related to the study of matter. The property of atoms and molecules to become excited when penetrated by only certain specific light

waves (remember the example with the switches), for example, is utilized to single out the isotopes we need from the mix in which they naturally occur. The basic ideas and methods of using laser radiation selectively on atoms and molecules was proposed by Soviet scientists at the USSR Academy of Sciences Institute of Spectroscopy. They are now extensively utilized in many laboratories both in the Soviet Union and abroad. The world's first successful experiments to isolate stable isotopes utilizing the radiation from a powerful laser were conducted jointly by specialists from this institute and the I. V. Kurchatov Institute of Atomic Energy.

Methods utilizing the selective effect of laser radiation provide the basis for a new approach to the technology of matter. Using beams of light, it is possible to manipulate atoms and molecules of a certain kind and collect microscopic quantities of matter composed of literally a single kind of atom or molecule. The most important process in this technology is undoubtedly the derivation of particularly pure substances, alloys, and molecular compounds. The first successful experiments to remove undesirable molecular impurities from a gaseous substance were conducted recently. Totally new avenues of research are opening up in nuclear physics, chemical technology, molecular biology, and so forth.

While expanding the field of application of spectroscopy, quantum electronics has also received an induced impetus from it, so to speak. The possibility of rapidly and simply studying the true structure of atoms and molecules and accurately finding the position of the midpoint of spectral lines has proved invaluable for monitoring and stabilizing the frequency of laser radiation. Methods for generating laser light with an ultra-stable frequency have been developed within literally a few years. Laser standards of frequency and length of unprecedented precision are already becoming part of laboratory measurement practice. The new laser standard of length, for example, makes it possible to measure distances comparable with the diameter of the earth with very great precision. This precision is by no means just some abstract record figure. It is extremely essential, particularly in the development of new instruments such as laser seismographs capable of "picking up" the small growing tensions in the earth's crust or in big buildings which precede earthquakes or other destructive processes. Therefore, every new degree of precision here means a very great deal. A unique laser facility built in the Siberian Department of the USSR Academy of Sciences under the leadership of Doctor of Physico-Mathematical Sciences V. Chebatoayev has achieved even greater relative precision in maintaining the frequency of laser radiation. The foundations of a new avenue of metrology--quantum otpical metrology--have been laid. Next items on the agenda are the introduction into metrology of a new laser standard of length, the development of apparatus for the direct measurement of the frequency of laser light in units of the atomic scale accepted throughout the world, and, eventually, the creation of a uniform laser standard of length and time. Institutes of the USSR Academy of Sciences are conducting this work in close cooperation with institutes of the USSR State Committee on Standards.

Thus, the results of work in the new field of science which has emerged at the point where quantum electronics meets optical spectroscopy have a broad range of applications--from fundamental research to technological processes at the atomic and molecular level. Soviet scientists have made a considerable contribution to the creation of this advanced field of science and technology. The further development of laser spectroscopy will contribute to the further strengthening of the link between fundamental and applied research and to the acceleration of our country's scientific and technical progress.

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SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

ACADEMICIAN MSITISLAV VSEVOLODOVICH KELDYSH

Moscow OGONEK in Russian No 27, Jul 78 p 4

/Text/ Soviet science has suffered a grievous loss. Academician Msitislav Vsevolodovich Keldysh, an eminent scientist of recent times, member of the Presidium of the Academy of Sciences USSR, chairman of the Committee for Lenin and State Prizes in the area of science and technology at the Council of Ministers USSR, deputy of the Supreme Soviet USSR, three times winner of the Hero of Socialist Labor died suddenly on 24 June 1978 at the age of 68 years.

M.V. Keldysh's name is associated with epochal achievement of Soviet and world science and technology, with the establishment of new scientific trends, with a major organizational role in the solution of major problems posed by the Communist Party and the Soviet government.

Keldysh was born in 1911 in Riga. After completion of studies at the Department of Physico-Mathematics of Moscow State University in 1931, he worked at the Central Aerohydrodynamic Institute imeni N. Ye. Zhukovskiy where he carried out several outstanding investigations in mathematics, mechanics and aerohydrodynamics. These studies advanced the development of the tradition of the eminent Russian mathematicians and mechanicians (P.L. Chebyshev, N.Ye. Zhukovskiy and S.A. Chaplygin), associated with basic research concerning the solution of specific practical problems. In a complex of brilliant mathematical studies, M.V. Keldysh solved complex problems in the area of the theory of functions of real and complex variable equations in partial derivatives, functional analysis and applications of the theory of harmonic functions. In the area of aerohydrodynamics, he produced fundamental results in the theory of unsteady motion of a wing, theory of movement of bodies under a liquid surface and the theory of streamline flow by a compressed liquid and an extension of the well-known N.Ye. Zhukovskiy theorem concerning lift. Soviet science owes much to M.V. Keldysh for the fact that our mathematical and aerodynamic schools occupy a leading place in world science. A major contribution to this

position was M.V. Keldysh's work concerning vibrations and autovibrations of aircraft structures (flutter and shimmy), which provided great impetus to the creation of the new technique in the World War II period.

M.V. Keldysh played a founder's role in the creation in the post-war years of contemporary basic scientific trends (computer mathematics, nuclear energetics and space research). Computer mathematics, arising from problems of the new technique based on classical mathematics and new computer devices, immeasurably expanded the possibilities and effectiveness of scientific research, greatly increased the rate of scientific progress. M.V. Keldysh participated in this titanic work not only as an author of many ideas and computer methods but also as director of a large collective of scientists. Many fundamentally important problems associated with the use of nuclear energy were studied on the basis of effective mathematical methods.

M.V. Keldysh made outstanding contributions to the development of Soviet space science and technology. He was one of the initiators of the wide development in our country of works involving the study and mastery of space and he directed a major part of their execution. Up until the last days of his life, he supervised these studies. The discovery of new horizons in the study of cosmic space, the formation of complex scientific-technical programs, problems concerning the dynamics and control of flights, scientific and practical results of the researches were an inherent part of his everyday activity.

Keldysh was an eminent science organizer. While heading the Academy of Sciences USSR from 1961 to 1975, he made outstanding contributions to the development of Soviet science.

Under his direction, the Academy of Sciences USSR conducted vast work on the realization of the decrees of the 22d, 23d and 24th Congresses of the CPSU in the area of science and scientific and technical progress, for the use of the achievements of science in bringing about the Communist construction. In this period, there arose and was developed new, major scientific centers of the academy; the network of scientific research institutes increased and the geographical locations were expanded; specialization was increased and coordination of their activity was amplified. The Academy of Sciences USSR became a mighty, active arm of Soviet science. All of Keldysh's organizational activity was characterized by proper determination of strategy of scientific research and by the relationship between basic and applied trends. He did much for the organization of international scientific collaboration, for coordination of the efforts of scientists of socialist countries.

M.V. Keldysh's services to Soviet and world science were highly regarded by the Communist Party and the Soviet government. Three times he was named

Hero of Socialist Labor, Lenin Prize and State Prize laureate and was awarded many orders or medals of the Soviet Union and socialist countries. He was elected a member of many foreign academies and was awarded Honorary Doctor degrees by several foreign universities. He was a member of the Central Committee of the CPSU and was elected deputy of the Supreme Soviet USSR of many congresses.

The broad outlook of the scientist-Communist, his profound moral fiber, his political approach to the solution of problems arising, his adherence to principle and devotion to the Fatherland in Party matters earned M.V. Keldysh great respect and authority. The name of this eminent scientist-Communist, who gave all his effort and capacity to selfless service to science, progress and the people will always be remembered in the hearts of the Soviet people.

L.I. Brezhnev, Yu.V. Andropov, V.V. Grishin, A.A. Gromyko, A.P. Kirilenko, A.N. Kosygin, F.D. Kulakov, D.A. Kunayev, K.T. Mazurov, A.Ya. Pel'she, G.V. Romanov, M.A. Suslov, D.F. Ustinov, V.V. Shcherbitskiy, G.A. Aliyev, P.N. Demichev, V.V. Kusnetsov, P.M. Masherov, B.N. Ponomarev, Sh.R.Rashidov, M.S. Solomentsev, K.U. Chernenko, I.V. Kapitonov, V.I. Dolgikh, M.V. Zimyanin, Ya.P. Ryabov, K.V. Rusakov, V.A. Kirillin, L.V. Smirnov, A.P. Aleksandrov, S.P. Trapeznikov, V.A. Kotel'nikov, A.A. Logunov, Ye.P. Velikhov, Yu.A. Ovchinnikov, A.V. Sidorenko, P.N. Fedoseyev, G.I. Marchuk, G.K. Skryabin, N.N. Bogolyubov, A.M. Prokhorov, M.A. Markov, B.N. Petrov, V.A. Ambartsyuman, N.G. Basov, P.L. Kapitsa, M.A. Lavrent'yav, B.Ye. Paton, A.N. Nesmeyanov, N.A. Pilyugin, A.S. Sadykov, I.M. Vinogradov, V.P. Glushko, V.N. Chelomey, Yu.B. Khariton, Ya.B. Zel'dovich, A.N. Tikhonov, R.Z. Sagdeyev, A.Yu. Ishlinskiy, N.N. Semenov, L.I. Sedov, K.N. Rudnev, Ye.P. Slavskiy, A.I. Shokin, V.P. Yelyutin, S.G. Shcherbakov, N.N. Blokhin, B.V. Petrovskiy, S.A. Zverev, M.S. Smirtyukov, V.N. Makeyev, V.A. Shatalov, I.D. Serbin, S.A. Afanas'yev, A.A. Dorodnitsyn, N.S. Arzhanikov.

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SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

UDC 53(092)

SERGEY MIKHAYLOVICH RYTOV

Moscow USPEKHI FIZICHESKIKH NAUK, AKADEMIYA NAUK SSSR in Russian Vol 125, No 3, Jul 78, pp 571-572

/Article by S.A. Akhmanov, F.V. Bunkin, A.G. Vinogradov, A.V. Gaponov, D.L. Goryshnik, Yu.A. Kravtsov, M.L. Levin, A.M. Prokhorov, V.I. Tamarskiy, I.L. Fabelinskiy and Z.I. Feyzulin/

/Text/ Sergey Mikhaylovich Rytov, eminent Soviet physicist and corresponding member of the AS USSR commemorated his 70th birthday 3 July 1978. His creative work, extending over a span of almost 50 years, is unusually diverse and fruitful. It is impossible not to admire the breadth of his scientific interests which embrace a multiplicity of different areas of physics, especially those which are associated with vibrational, wave and fluctuation phenomena. Studies conducted by S.M. Rytov in optics, electrodynamics, acoustics and radio engineering had a significant influence upon the establishment of radio physics and opened broad prospectives for its future development. Academician A.L. Mints once said, "Radio physics is the central thing that occupies Sergey Mikhaylovich Rytov" and this witty definition very accurately reflects the contribution of S.M. Rytov to contemporary radio physics.

It is not possible to present here a complete analysis of the works of S.M. Rytov, however, some of them are so important for the establishment of radio physics as a science that it is impossible not to mention them. First, we must point out his doctoral dissertation "Modular Vibrations and Waves" (1938; published in "Transactions of FIAN /Physics Institute imeni P.M. Lebedev of the Academy of Sciences/ USSR in 1940), which had a vast influence upon development of the theory of vibrations and clearly demonstrated the fruitfulness of a sequential vibrational approach to different problems of physics. This classical work is still as up to date today as it was at the time of publication.

Sergey Mikhaylovich was occupied with problems of the theory of waves and vibrations, later, obtaining important results in the theory of autovibrations of Thomson type systems, in the theory of betatron and synchroton

vibrations, in the theory of parametric generators and amplifiers (1948-1963). Studies in these directions were developed successfully by students and followers of Sergey Mikhaylovich.

Another fundamental work by Sergey Mikhaylovich involved the study of diffraction of light by ultrasound (Herald of the AS USSR, "Physics" series, 1937, No 2, p 223). Results of this study have now become especially important in connection with the rapid development of a new practical area of radio physics (acousto-optics). In this study, Sergey Mikhaylovich developed an effective method of analysis of waves and continuously inhomogenous media which later was named the Rytov method. Now, this method has become an important means of analysis of one of the basic problems of radio physics, that is, wave propagation in randomly-inhomogeneous media.

An important place in the creative biography of S.M. Rytov is occupied by studies of thermal fluctuations. He wrote 2 monographs concerning thermal fluctuations (Theory of Electrical Fluctuations and Thermal Radiation, 1953 and Theory of Equilibrium Thermal Fluctuations in Electrodynamics, 1967, which was written in collaboration with M.L. Levin). The theory developed by S.M. Rytov provides a unified description of thermal fluctuations of an electromagnetic field in all ranges of frequencies and is used extensively in the most diverse areas of physics. Later, these results were generalized for fluctuation fields of any nature (1973).

Sergey Mikhaylovich developed the most general phenomenological theory of the spectral composition of molecular scattering of light, including the spectrum of depolarization radiation, the Mandel'shtam-Brillouin spectrum and the spectrum of scattering, caused by fluctuations of entropy (1955-1970). This theory is well confirmed by many experiments and has received general recognition.

In the most recent years, Sergey Mikhaylovich has been fruitfully occupied also by problems of the progapation of radio waves in the ionosphere and by the theory of fluctuation phenomena during propagation and diffraction of waves in randomly-heterogeneous media. Part of these results are summed up in widely known reviews, published in UFN /Progress of Physical Sciences/ (1970 and 1975).

S.M. Rytov's fruitful scientific activity is inseparably connected with pedagogical activity, which he began even before graduation from college. For the last 3 decades, he has continuously directed the Chair of Radio Physics, established by him at MFTI /Moscow Physico-Technical Institute/. Each person who has been fortunate enough to hear Sergey Mikhaylovich, has been delighted by his mastery in lecturing, by the fine form and utmost clarity of all of his statements whether it be a lecture, an address or a short remark. Lectures concerning statistical radio physics which he read at MFTI served as a basis for the creation of the world's only textbook

on statistical radio physics ("Introduction to Statistical Radio Physics" (1966) which immediately became a scientific bestseller). "Introduction to Statistical Radio Physics" is a reference book not only for students in radio physics specialties but for all Soviet radio physicists. This book is now being published in a 2-volume edition (part 1, "Random Processes" issued in 1976 and Part 2 "Random Fields" written in collaboration with Yu.A. Kravtsov and V.I. Tamarskiy will be released this year), which presents new results of the last decade.

In his scientific and pedagogical activity, S.M. Rytov is continuing the best traditions of the school of his teacher, academician L.I. Mandel'shtam, which is distinguished by its profound penetration into the physical essence of the phenomena considered, by the skill to formulate a problem clearly, by its encyclopedic content, boundless devotion to science and by the extreme demands upon himself. Sergey Mikhaylovich constantly implants these beautiful traditions of science in youth. Thanks to the vast work performed by him on the collection, development and editing of L.I. Mandel'shtam's lectures, they have become the property of the young generation of physicists.

A vast influence on the development of domestic radio physics has been exerted by the All-Moscow Radio Physics Seminar created by him at the sessions of which (at first at FIAN and then, since 1971, at the IFA of the AS USSR) are heard and discussed the most essential works on radio physics and adjacents areas of science. The prestige of Rytov's seminar has become so great that it was recently transformed, in essence, from an All-Moscow seminar into an All-Union seminar; participants now include scientists from Gorki, Khar'kov, Leningrad, Tomsk and other towns. The number of sessions of the seminar already has exceeded 500. Sergey Mikhaylovich has the astonishing skill to quickly and accurately evaluate studies delivered and to indicate the strong and weak points. His opinion, as a rule, is the determining one, especially in dealing with matters concerning a review of established views. He is frequently sought for advice by representatives of related specialties: radio astronomy, optics, specialists in the area of geophysics and biophysics, etc. This is facilitated by the special atmosphere of supportive interest toward science, of good will and mild humor, which Sergey Mikhaylovich creates at his seminars. Therefore, it is not astonishing that not only his immediate students and associates but also many scientists joyfully align themselves to S.M. Rytov's school at which the intellectual intercourse with Sergey Mikhaylovich is clearly evident.

The scientific-public and organizational work of S.M. Rytov is not limited to directing a seminar. He is a member of the editorial board of the journal "Radio Engineering and Electronics" chairman of a section of the Scientific Council of the AS USSR on the problem "Statistical Radio Physics",

a member of the Bureau of the Scientific Council of the AS USSR on the complex problem "Propagation of Radio Waves," a member of the Methodical Council of the AS USSR on physico-mathematical sciences of the All-Union Society "Znaniye" and others.

S.M. Rytov's services to Soviet science is generally known. He was awarded the Gold Medal imeni A.S. Popov and the Prize imeni L.I. Mandel'shtam. He was awarded the Order of the Red Banner three times, the order of the "Badge of Honor" and medals of the USSR.

He greets his 70th birthday in the bloom of creative strength. As before, he is full of energy and new ideas. With all our heart, we wish Sergey Mikhaylovich further successes in all his affairs.

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IN MEMORY OF F. I. VILESOV

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA. SERIYA -- FIZIKA I KHIMIYA in Russian No 10, May 78 pp 145-146

[Obituary]

[Text] Soviet science has suffered a severe loss: on 7 February 1978 Professor Fedor Ivanovich Vilesov, Doctor of Physical and Mathematical Sciences, died suddenly.

A large portion of the short and brilliant life of Fedor Ivanovich Vilesov was connected with Leningrad State University, where he traveled the path from student to pro-rector of the university for scientific work, head of the Department of Photonics of the Physics Faculty, and head of a large division of the Scientific Research Institute of Physics of Leningrad State University.

F. I. Vilesov was a brilliant experimental physicist, one who worthily continued the glorious traditions of the scientific school of his teacher, Academician A. N. Terenin. He is well known in our country and abroad for his work on a broad circle of problems connected with the active intervention of light with isolated and adsorbed molecules and with the surface of a solid. Such a broad inclusion of mutually related problems permitted F. I. Vilesov to always find the most urgent directions and methods of investigation. He is credited with the pioneering work to obtain the energy spectra of electrons liberated during the photonization of molecules by vacuum ultraviolet radiation. That work led to the development of a new spectroscopic method -- photoelectron spectroscopy, which is now successfully used in many laboratories of the world to investigate the processes of photoionization and study the electronic structure of molecules. F. I. Vilesov and his students were the first in the USSR to use methods of mass-spectrometry and ion-electron collisions to investigate processes of photoionization. He successfully used the new methods in systematic comprehensive investigations of the processes of photoionization of many classes of organic compounds, and the industrial photoelectronic spectrometers and photoionization mass-spectrometers developed under his scientific supervision made it possible to introduce modern methods of scientific research in a number of physics, chemical and biological institutes of the USSR.

F. I. Vilesov and his pupils have conducted investigations of elementary photochemical processes with the formation of excited atoms and radicals, investigations important for the chemistry of lasers. His investigations of the photonics of heterogeneous systems -- determination of the ionization potentials of adsorbed molecules, study of the processes of their photoactivation and the working out of problems of the photosensitization of semiconductors -- constituted a considerable contribution to science. In recent years F. I. Vilesov gave much attention to urgent investigations in the area of photocatalysis in connection with the use of solar radiation for purposes of power engineering, purification of the environment and regeneration of components of the atmosphere by photochemical methods.

Characteristic of the scientific activity of F. I. Vilesov was a constant striving to walk new paths, to develop original methods and to combine basic research with the solution of practical problems. He was the author of over 150 scientific publications.

F. I. Vilesov receives much credit for the training of personnel for a new area of science -- photonics. For 10 years he headed the Department of Photonics of Leningrad State University. Tens of his pupils are successfully working in many cities of the USSR. Among them are 17 candidates of physical and mathematical sciences.

A talented scientific organizer, F. I. Vilesov headed the Main Council for General Physics of the Ministry of Higher and Secondary Specialized Education RSFSR, was a member of the Photochemistry Section of the Scientific Council for High-energy Chemistry of the Academy of Sciences USSR, the Council for Physical Electronics of the Academy of Sciences USSR, the Interdepartmental Commission for Spectral Instrument-Making and the Commission for Synchrotron Study under the Presidium of the Academy of Sciences USSR, and was a member of the editorial board of two scientific journals.

The memory of Fedor Ivanovich Vilesov, an eminent scientist, wholly devoted to science, will always be preserved in our hearts.

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